Email:editorijless@gmail.com
Volume: 7, Issue 4 , 2020 (Oct-Dec)

INTERNATIONAL JOURNAL OF LAW, EDUCATION, SOCIAL AND SPORTS STUDIES (IJLESS)

A Peer Reviewed and Refereed Journal

DOI: 10.33329/ijless

http://ijless.kypublications.com/

ISSN:2455-0418 (Print), 2394-9724 (online)

www.kypublications.com

Impact Factor 6.0176 (ICI)

International Journal of Law, Education, Social and Sports Studies (IJLESS)
Volume: 7, Issue 4, 2020 (Oct-Dec)
ISSN: 2455-0418 (Print), 2394-9724 (online)
Research Article

A STUDY OF SOME CURRICULAR ISSUES AT TEACHING THE CONCEPT OF ELECTROMAGNETISM IN IVORIAN HIGH SCHOOLS

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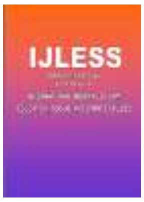

ABSTRACT

The teaching of electromagnetism at the Ivorian high educational system is organized at three levels of education: 3rd year of high school; 2nd and 3rd year of high school in science.High school teachers have shortcomings in the conceptualization of the notion of electromagnetism, which are accentuated in the latter by the difficulties in transferring mathematical notions used in physics classes.To do this, we observed ten (10) teachers in a classroom situation using two grids whose observations focused on the identified components of the founding concepts of electromagnetism and those used in mathematics.The results reveal the weakness of teaching / learning in terms of taking into account all of the founding concepts, which is punctuated by the lack of laboratory tools and overcrowded classes, preventing teachers from giving meaning to some essential notions of electromagnetism in physics class.

Keywords : Didactics, Founding concept, Electromagnetism, Transfer, Physics, Secondary.

Résumé

Les enseignants du secondaire présentent des insuffisances dans la conceptualisation de la notion de l'électromagnétisme, lesquelles sont accentuées chez ces derniers par les difficultés de transfert des notions mathématiques mobilisées en classe de physique.

Pour ce faire, nous avons observé dix (10) enseignants en situation de classe à l'aide de deux grilles dont les observations ont porté sur les composantes identifiées des notions fondatrices de l'électromagnétisme et celles mobilisées en mathématiques.

Les résultats révèlent la faiblesse de l'enseignement/apprentissage au niveau de la prise en compte de l'ensemble des notions fondatrices, laquelle est ponctuée par le manque d'outils de laboratoire et les classes surchargées, empêchant les enseignants de donner du sens à certaines notions essentielles de l'électromagnétisme en classe de physique.

Mots clés : Didactique, Notion fondatrice, Électromagnétisme, Transfert, Physique, Secondaire.

INTRODUCTION

In middle school, the program aims to reinforce the founding notions of magnetism and those of electricity. In high school, the program gives an important place to these concepts and offers a concrete and contextualized approach. It aims to allow students to access, within the framework of electromagnetism, a detailed understanding of the phenomena addressed and to make them perceive the unifying and universal scope of its laws. However, the ways of thinking specific to the founding notions of electromagnetism are acquired through a limited body of knowledge, know-how and methods which find their effectiveness in the additional insights provided by mathematics through its mobilized notions. .

The teachers of these two disciplines are called upon to work jointly on the concepts which lend themselves to a crossing. Unfortunately, the contributions of each of these two disciplines to enrich the understanding of common concepts pose enormous difficulties for physics teachers. Indeed, the wide range of scientific languages in physics, whether at the level of the experimental approach with the measurements and their graphic operations, or at the level of the modeling approach with the development and use of literal relations between quantities physical (scalars, algebraic, vectorial, differential) is a source of multiple difficulties for students. They would be linked to problems of mastering certain mathematical concepts and tools (proportionality, literal calculation, units and conversions, powers of ten, vectors, projections, primitives, etc.) among teachers.

In the Ivorian context, the difficulties of physical-mathematical interaction affect not only the mastery of the knowledge to be mobilized in the source situation but also and above all the degree of organization and structuring of the teacher's knowledge (Moffet, 1993) .These difficulties have significant impacts, especially when it comes to teaching this concept to students.This work sheds light on the relationship between physics high school and college teachers with the founding notions of electromagnetism and those used in mathematics to effectively conceptualize the notion of electromagnetism in physics class.

RESEARCH ISSUE

The analysis of the content of programs and textbooks in use in physics and mathematics under the perspective of didactic transposition revealed that the concepts of magnetic and electrostatic fields, and of vectors are very present in secondary education programs and they play an important role in the development of the various study topics. However, bibliographic analysis has shown us the existence of significant difficulties related to the use of these concepts among teachers. The contextualization of the notion of electromagnetism, the study of representations and conceptions of electromagnetic phenomena, remain fragmentary.

Regarding the mobilization of the founding notions of electromagnetism for a better construction of knowledge in physics class, the studies have been carried out and for the most part, they examine more the difficulties in the pupils. Regarding teachers, we note conceptual difficulties in understanding the different aspects of the concept of electromagnetism. The major problem undoubtedly remains the transition from mathematical knowledge to reusable knowledge in the field of physics. The aspects raised concern not only the bad articulation between mathematics and physics, but also and especially the low level of transfer of properties, theorems, mathematical laws of the teachers as for their coherence and effective use in physics class.

RESEARCH QUESTIONS

In the secondary electromagnetism (magnetism and electricity) program, as we have already specified previously, this concept of electromagnetism takes into account several notions and their understandings are subject to representations. The research question that arises from the context of teaching and the existence of these representations is as follows : How do physics teachers relate to the founding notions of electromagnetism on the one hand ; and how do they manage the transfer of mathematical notions used in physics class on the other hand ?

CONCEPTUAL FRAME

Long-privileged relationships between physics and mathematics have undergone significant changes between rapprochement and rupture (Henry in Toussaint, 1996; Artaud, 1999; Ba, 2011). These changes have influenced the development of the two disciplines and consequently teaching practices. The constitutive relationships between mathematics and physics allow a double emergence of concepts (Robert and Treiner, 2009). Indeed, the close collaboration between the two disciplines was at the origin of the invention and development of several concepts. This is the case with the calculations of derivatives and differentials invented by Newton and Leibniz which enabled the two disciplines to formulate natural laws and to develop large theoretical models (Henry in Toussaint, 1996).

In the context of mathematical modeling, it is essential to associate the semiotic register with the framework of rationality (Douady, 1984 and Lerouge, 1992) which gives it meaning especially since the approach adopted in teaching favors a didactic treatment based on a Implicit homomorphism between the concept in the context of mathematics and that in the context of physics (Malafosse and Dusseau, 2001).

However, the choices of concepts in the programs, their underlying epistemologies, and their interpretations by teachers depend on their own training (Henry, 1996). These choices affect the learner's learning process and his ability to mobilize mathematical knowledge in the field of physics. This mobilization depends on the extent of mastery of this knowledge in the context of mathematics (source situation), on the meaning given to the learning, on the understanding of the target situation (framework of physics) and the why calls on such knowledge acquired in a source situation in such a target situation (Forcier and Goulet, 1996). The aptitude for transfer depends, of course, on the degree of mastery of the knowledge to be mobilized in the source situation, but also on the degree of organization and structuring of this knowledge (Moffet, 1993). The mobilization of knowledge built in a source situation A (initial acquisition situation) to a situation B (target situation) requires the transferor, among other things, to establish links between the initial acquisition framework and the new framework.

The founding concepts of electromagnetism in connection with the mathematical concepts used require students to master the two frames, "source" frame and "target" frame. Unfortunately, the contradictory approaches (Induction / Deduction) between these two frameworks (Lerouge, 2000; Malafosse et al, 2000) constitute enormous difficulties in terms of the understanding and adequate use of these concepts. Studies have shown that the concept of vector field is poorly understood by learners. For the latter, the field is a physical quantity, function of the position coordinates of a point in space and time, which can be represented by a vector, used to locally describe the properties of matter or to interpret the phenomena that occur there. At most, some make the connection with some of the characteristics of a vector, without ever mentioning the specific characteristics of the physical quantity (Albe and Venturini, 2001). It must be said that the very concept of a vector is much more complex than it seems. According to a survey (Fabre, 1992), the majority of terminal students do not know all the characteristics of the vector. Lounis (1990) showed that the students of Seconde privilege the scalar aspect of the vector physical quantities (in this case the force and the speed), compared to their characteristics of spatial orientation.

METHODOLOGY

Target population and study participants

This research targets secondary school teachers who come from four (4) public secondary schools of the regional directorate of national education (DREN) in Dabou, a city located less than fifty kilometers from the economic capital Abidjan. A target population of 10 who teach in the 3rd year of middle school (Grade 8), in the 2nd year of high school (Grade 11) and in the 3rd year of high school (Grade 12) of scientific fields.

With the contribution of 5 teachers from high schools and colleges other than the ten (10) first selected for the final test, we have associated five (5) expert teachers (experienced teachers having been practicing for 20 years and more) from high schools and colleges, two (2) advisers and one (1) educational inspector as part of a "focus group" to further explain the questions of the final test. Participation in the study was on a voluntary basis.

Data collection

We agree with Guba and Lincoln (1994) that the qualitative / interpretive research used in this work fundamentally calls for qualitative tools. Indeed, the term "qualitative" relates mainly to the type of data used, ie "data that is difficult to measure" (Savoie-Zajc, 2004). Words, observations, statements coming from programs, textbooks are examples of qualitative data.

The answer to the questions in the questionnaire was used as the first data collection tool. The semi-structured interview with students and teachers of the diagnostic test was used as a second data collection tool to make the questions accessible and consistent. The "focus group" discussion group with expert teachers was chosen as a complementary tool to make the different questions of the questionnaires of the final test understandable. All discussions were recorded on tape recorder.

Research progress

The diagnostic test

The TIAPANI high school was selected for the diagnostic test. To validate the various questions, we checked and commented on the data collected as part of the "focus group" discussion group set up. This test made it possible to identify the founding concepts of electromagnetism and those used in mathematics. Two (2) grids of the objects of observation of the concepts identified were validated for the services of teachers such as the final test.

The final test

Teachers from high schools and colleges (N = 10) were monitored using two observation grids, one for the objects of observation of the founding concepts of electromagnetism; and the other for the mathematical notions involved. Their evaluation took place in two laboratories of the TIAPANI Dominique high school with the different classes constituted by the students (3rd year of college, 2nd and 3rd year of high school) in the presence of a teacher, an educational advisor and an educational inspector of physics and chemistry by laboratory. The researcher played the role of coordinator of the activities of the two laboratories. We have retained by chapter two courses given by two teachers in the two laboratories at the same time. The experiment took into account all of the chapters. This phase, which took the following groups of students : 3rd year of college, N = 90 students grouped into 2 classes (due to 45 students per class) ; 2nd year of high school scientific stream, N = 80 students grouped into 2 classes (due to 40 students per class) ; 3rd year of high school science course, N = 60 students grouped into 2 classes (due to 30 students per class).

Data processing and analysis

This section discusses the procedure for processing and analyzing the data collected through the questionnaire. In order to "construct a meaning" to the corpus of raw data, we have had recourse to the methodological approach to processing and analyzing data which respects an inductive logic, namely an approach compatible with the epistemological posture of hermeneutical understanding. (Paillé and Mucchielli, 2003, 2012) as well as with the objectives of this research. For qualitative data, Multiple Correspondence Factor Analysis (AFCM) was used as a basis for classification. This is the case for questions dealing with the way in which teachers stress certain notions. This makes it possible to note the degree of importance of the founding notions and of the mathematical notions mobilized by assessing the following characteristics:

Very Important / Important / Not Very Important / Without indication from the teacher.

Table 1: Descriptive scale based on a qualitative linked to the degree of importance of the concept

	Very important	Important	Not Important	Without indication
Evaluation criteria	The information given to the students by the teacher on the concept is considered relevant. He emphasizes the notion by drawing their attention.	The information given by the teacher on the concept has the essential characteristics. It can be assessed in a classroom activity.	The information given by the teacher is not very correct.	Information given without any provision

Significance is related to the degree to which the teacher insists on the concept during teaching or the special attention that the latter requests from the pupils in the context of a possible classroom assessment. On the other hand, for questions leading to a degree of satisfaction, according to a qualitative assessment scale by Côté (2014) described by the performance levels associated with the following degrees of satisfaction. :

Superior / Satisfactory / Sufficient / Insufficient

Table 2: Descriptive scale based on a qualitative linked to the degree of satisfaction

	Superior	Satisfactory	Sufficient	Insufficient
Evaluation criteria	The information given by the teacher on the concept is not only correct, but also relevant and abundant.	The information given by the teacher on the concept has the essential characteristics. It can be assessed in a classroom activity.	The information given by the teacher is not very correct.	Information given without any provision

Results

Relationships of high school and college teachers with the founding concepts of electromagnetism

To prepare and deliver the teaching sequence on the notion of electromagnetism, it is important for the teacher to have a good command of the objects of observation which characterize the founding concepts of this notion. We evaluate the didactic transposition (the capacity of the teacher to transform the notion in physics into a teaching object, which implies, among other things, the ability to establish links between the different objects of observation of the founding notion) according to the presence of the teacher to judge his quality of the following indicators: mastery of the concept (accuracy, relevance), importance of the concept (insistence).

Table 3 shows Percentage of high school and middle school teachers assigned to each level of importance of the objects of evaluation of the founding concepts of electromagnetism.

Table 3: Percentage of high shool teachers in chage of high school and college teachers assigned to each level of importance of the objects of evaluation of the founding concepts of electromagnetism

Foundations of electromagnetism	Assessment objects			Very important	Important	Not important	No response
				Percentage of teachers assigned to each level of importance of the objects of evaluation of the founding concepts of electromagnetism			
Magnet	*Properties*	*Attraction/Repulsion*		36	38	11	5
		Magnetic field		30	40	20	10
	Bipolar	*North Pole*		33	32	22	13
		South Pole		33	32	24	11
	Compositions	*Neodymium magnets*		25	30	30	15
		Ferrite magnets		33	32	20	15
	Types	*Permanants*		31	39	20	10
		Temporary		31	38	21	10
Compass	*Magnetic needle*	*North Pole (red)*		29	40	20	11
		South Pole		30	40	18	12
	Always indicates magnetic north			28	38	22	12
Coil	*Conductor wire winding*	*Resistance*		26	34	26	14
		Inductance		25	35	26	14
Electrical charge	*Is a fundamental property of matter*			25	33	28	14
	Types	*Charged*	*Attraction*	29	41	18	12
			Repulsion	29	40	20	11
		Neutral		33	39	18	10
	Is quantified			25	35	22	18
	Elementary			27	34	25	14
Electrical power	*Circulation of electrical charges*			25	38	24	13
	Knowing how to represent and measure it			26	37	23	14
	Rigorously use the law of knots			25	37	22	16
	The direction of the electric current is that of the displacement of the positive charges.			20	27	35	18
	Charged particles	*Electrons in a metal*		26	37	21	16
		Holes		17	31	36	16
		Ions in an electrolyte		26	36	26	12
	Ammeter, device for measuring its intensity			26	32	24	15
	Deflect the compasses			20	27	33	20
Electric tension	*Is one of the quantities defining the electrical state of a point in space.*			26	36	20	16
	Is an algebraic quantity			27	33	24	16
	Knowing how to represent and measure it			26	34	23	17
	Rigorously use the mesh law			27	33	25	15
	Is measured using a voltmeter			27	37	21	15
Space	*Designates an extent, a surface, a region*			25	36	25	14
Champ	*A physical quantity present at each point of the considered space.*			15	25	21	32
	Is always tangent to the field line, in the direction of the line.			25	39	24	12
	Types	*Scalar*		18	29	31	22
		Vectorial		19	31	24	14
Field lines	*Never intersect*			25	35	25	15
	Are oriented in the direction of the field			20	24	36	20
	The field is always tangent to the field line, in the direction of the line.			23	37	24	16
	The strength of the field is proportional to the density of the field lines.			18	26	36	20
	The closer the field lines are to each other, the stronger the field.			22	36	26	14

	Determine the direction and orientation of the field	24	36	24	16
Electrical field	*Is manifested in the presence of positive or negative charges.*	16	24	32	22
	Is associated with the presence of an electrical voltage	15	28	33	24
	Is a vector field	25	38	23	14
	Appears as soon as there is voltage, for example, approximation of an electrical outlet.	24	35	27	14
	Is due to the presence of an uneven distribution of electrical charges of different polarities	15	27	33	25
	Exists even if no current is flowing.	15	31	31	23
	Implies lamp off or on	16	31	29	24
	The higher the voltage, the stronger the electric field.	24	38	23	15
	Est une région de l'espace où s'exerce une force sur une charge d'essai électrique.	24	37	23	16
Magnetic field	*Is a region of space where a force is exerted on an electrical test load.*	21	23	33	23
	Is created by the passage of an electric current.	24	34	26	16
	Is all the more intense the closer you are to the source and it decreases rapidly as the distance increases	27	33	23	17
	Characterizes the influence of a moving electric charge and exerts an action on the moving charges.	15	25	35	25
	Appears when there is an electric current flowing through a conductor.	26	35	25	14
	Involves lamp on.	14	26	36	24
	Lamp off implies absence of magnetic field	15	24	32	28
	Without current flow, no magnetic field is created.	16	27	35	22
	Moving charges generate a magnetic field, so a direct current causes a magnetic field	5	12	14	28
	Is a vector field.	5	31	36	19
	A variation in electric field generates a magnetic field.	15	24	36	25
Earth's magnetic field	*Is generated by the movements of the liquid metallic core of the deep layers of the Earth.*	13	27	37	23
	Is therefore represented at any point by a vector which has for direction and direction those of the axis SN of the magnetized needle of a compass (the vertical plane of the needle defines the magnetic meridian plane).	18	22	34	26
	Can be compared to a straight magnet or a flat coil carrying a current.	34	42	14	10
	North / South magnetic pole	20	24	32	24
	The magnetic induction vector B has a vertical component Bv (directed towards the center of the Earth) and a horizontal component B0	26	40	21	13
	Geometric North / South pole	17	26	31	26
	The angle formed by B and B0 is called "inclination"	2	27	26	19
	Magnetic equator	16	28	33	23
	Is a vector quantity.	24	36	27	23
	Pour se le représenter facilement, il suffit d'imaginer un aimant droit incliné d'environ 10° par rapport à l'axe de rotation terrestre.	20	26	32	22

Electromagnetic induction	*To easily imagine it, just imagine a right magnet inclined by about 10 ° with respect to the axis of Earth's rotation.*	21	20	36	23
	A circuit moving in a permanent magnetic field can behave like a voltage generator : it is the site of a Lorentz induction phenomenon.	21	24	35	20
	When a fixed circuit is subjected to a variable magnetic field (alternator), it is still the site of a Neumann induction phenomenon.	26	43	21	10
	Manifested by an electric potential which appears at the ends of a conductor which moves in a magnetic field.	20	21	28	21
	The phenomenon of induction is the appearance of an electric current inside a circuit without a generator.	17	27	35	21
	Predict the sign of induced current using Lenz's law	20	26	32	22
	Is the production of an electrical potential difference, coming from two terminals (one positive, the other negative) of a generator and which circulates in an inductor.	20	25	32	23
	The phenomenon concerns the solenoids	27	45	21	17
Auto-induction	*The coil opposes the variation of the magnetic field that it creates itself.*	14	28	38	20
	A high inductance coil will show a strong self-induction phenomenon with high voltage during current variations.	15	28	35	22
	Is the production of an electrical potential difference, coming from two terminals (one positive, the other negative) of a generator and which circulates in an inductor.	27	35	27	11
	The phenomenon concerns the solenoids	17	23	35	25

From the reading of table 3, we note that the percentage of teachers granted to essential knowledge considered essential to the construction of knowledge relating to the notion of electromagnetism remains low, as evidenced by the massive presence of the yellow color relating to the response rate sufficient not accessing 50%. The teachers privilege only a few of these basic essential notions for a contextualization of the notion of electromagnetism. Which seems detrimental to the conceptualization of this notion. Indeed, the analysis of Table 5.8 suggests the following observations:

- Regarding the notion of magnet, an average of 74% response (Very important + Important); which indicates the observed teachers have a better understanding of the properties of the magnet; the examples they use help to understand the properties of the magnet. We note that the notion of magnet is seen in elementary school and in the 3rd year of middle school.
- For the notion of compass, we note nearly 72% of response (Very important + Important); this shows that the teachers observed took ownership of the compass experiment. The strategies used by teachers make it easier to understand how the compass works.
- As for the notion of coil, an average of almost 55% of response (Very important + Important); which indicates its experimentation is not very easy among teachers. Teachers find it difficult to experiment.
- The results relating to the notion of electric charge indicate an average response of 66% (Very important + Important); which shows that the knowledge of the observed teachers of electric charge enables them to adequately describe and explain the components of this notion.
- Concerning the notion of electric current, we note an average of 59% of response (Very important + Important); which proves that the observed teachers have acceptable knowledge of the properties

of electric current. We note that 3 of the 6 response components (Very important + Important) are below the average.

- Concerning the concept of electric voltage, nearly 65% of teachers insist on the characteristics of electric voltage. Their explanation facilitates the understanding of the concept of electric voltage.
- For the concept of space, we only have a response percentage of 54% (Very important + Important) ; which shows that just over half of the teachers make it easier to understand the concept.
- Regarding the notion of field, we note a response percentage of 55% (Very important + Important) ; which clearly illustrates the acceptable effort of teachers to facilitate understanding of the concept of field at the level of the students questioned. However, 2 out of 4 components did not receive the appropriate attention from teachers.
- For the concept of field lines, we record a response percentage of 53% (Very important + Important); This shows that the teachers do not insist in the same way on the components of the concept: 2 components out of 6 are hardly have not received the attention of the teachers.
- Concerning the notion of electric field, we note only a percentage of 47% of response (Very important + Important); this low rate demonstrates the notorious insufficiency of the experimentation of the notion of electric field: difficult to insist on the essential components to make this notion comprehensible. More than half of the components do not benefit from the attention of the teachers observed.
- As for the notion of magnetic field, we recorded a response percentage of 44% (Very important + Important) among the teachers observed, the components of the notion of magnetic field on which the evaluations were based did not benefit from sustained attention from teachers. This low rate demonstrates the notorious insufficiency of the experimentation of the notion of electric field: difficult to insist on the essential components to make this notion comprehensible. More than half of the components (7/11) do not benefit from adequate experiences for their efficiency and effectiveness characterization in the teachers observed.
- For the notion of the terrestrial magnetic field, the response rate (Very important + Important) is 51%; the components of the notion of the Earth's magnetic field on which the evaluations focused have not received sustained attention from teachers. This low rate demonstrates the notorious insufficiency of the experimentation of the concept of electric field in physics class. Almost half of the components (3/7) do not benefit from adequate experiences for their efficiency and effectiveness characterization among the teachers observed for the students.
- Concerning the notion of electromagnetic induction, the response rate (Very important + Important) is 47%; which indicates the observed teachers have difficulty characterizing this notion. The components of the notion of magnetic induction on which the evaluations focused have not received sustained attention from teachers. This low rate demonstrates the notorious inadequacy of the implementation of the concept of magnetic induction in physics class. More than half of the components (4/6) do not benefit from adequate experiences for their efficiency and effectiveness characterization among the teachers observed.
- Regarding the concept of self-induction, we note a response rate (Very important + Important) of 47%; this low rate demonstrates the notorious insufficiency of the experimentation of this notion in physics class. More than half of the components (3/4) do not benefit from adequate experiences for their efficiency and effectiveness characterization among the teachers observed.

Table 4 lists the percentage of teachers assigned to each level of importance of the objects of evaluation of the mathematical concepts used.

Table 4: Percentage of teachers assigned to each level of importance of the objects of evaluation of the mathematical concepts used.

Foundations of electromagnetism	**Mathematics**		**Percentage of teachers according to their level of importance to each object of evaluation of the mathematical notions used**			
			Evaluation criteria			
	Notions mobilized	***Assessment objects***	**Very important**	**Important**	**Not important**	**No indication**
Electric field	**Vector**	*Meaning*	27	27	28	27
		The direction	26	28	30	25
		The module	25	28	30	27
		The proportionality coefficient	24	26	25	27
		Schematization	25	25	27	28
		The analytical expression	23	26	27	26
		Graphic representation	22	23	24	27
	Vectors overlay	*Meaning*	19	21	20	37
		The direction	20	20	20	35
		The module	19	20	21	37
		Vector calculus	20	20	22	33
		The parallelogram method	28	23	24	14
		Chasles equality	23	24	25	15
		The proportionality coefficient	21	19	21	38
		Schematization	20	20	19	39
		The analytical expression	22	18	18	34
		Graphic representation	22	20	20	37
	Scalar product	*The square root*	24	23	25	23
		Thales theorem	25	23	26	21
		The Pythagorean theorem	23	25	27	24
		The law of cosines	22	18	22	33
		Calculation from standards and an angle	22	18	20	36
		Calculation with an orthogonal projection	22	20	19	37
		Calculation only with standards	22	20	20	35
		Calculation in an orthonormal coordinate system	24	25	26	24
Magnetic field	**Vector**	*Meaning*	23	24	30	23
		The direction	26	22	25	26
		The module	24	25	28	23
		The proportionality coefficient	24	21	25	24
		Schematization	24	25	27	23
		The analytical expression	24	25	28	23
		Graphic representation	23	25	27	24
	Vectors overlay	*Meaning*	22	18	20	36
		The pairs of points of the same direction	24	25	27	22
		The direction	21	20	21	35
		Straight lines in the same direction	24	25	28	22
		The module	18	20	21	36
		Segments of the same length	18	20	21	23
		The proportionality coefficient	26	24	20	21
		Schematization	18	22	21	37
		The analytical expression	19	20	22	33
		Graphic representation	18	20	20	38
	Vector product	*Resultant* — *Laplace force case*	19	20	20	34
		Resultant — *Lorentz force case*	18	20	21	36
		The parallelogram area	24	23	27	25
		Ampère's man method	22	18	20	35

		Field orientation	*three fingers method of the right hand*	21	20	19	38
			Open hand method	19	19	20	33
			Unscrewing corkscrew method	22	19	19	35
Earth's magnetic field	**Vector**	*Meaning*		22	23	21	37
		The direction		21	18	20	36
		The module		18	20	23	34
		Schematization		18	18	20	33
		The analytical expression		19	16	23	38
		Graphic representation		18	20	21	34
		Use in the context of inclination I		18	18	20	37
		Use in the context of declination D		17	19	20	36
Electromagnetic induction	**Scalar product**	*The square root*		24	25	27	10
		Thales theorem		23	25	26	25
		The Pythagorean theorem		25	25	26	23
		The law of cosines		20	18	22	38
		Calculation from standards and an angle		19	18	20	38
		Calculation with an orthogonal projection		19	20	19	40
		Calculation only with standards		22	25	27	25
		Calculation in an orthonormal coordinate system		22	25	27	24
	Integral calculation	*Terminals*		23	25	28	25
		Area calculation		19	20	20	38
		The volume calculation		18	18	22	37
		The approximate calculation of an integral		18	17	24	39
		Integration by parts		19	18	21	38
Auto induction	**1st order differential equation**	*The initial conditions*		23	25	26	24
		The homogeneous equation		24	25	26	23
		Solving the homogeneous equation		23	25	27	24
		The homogeneous solution		24	24	28	22
		The search for the specific solution		23	21	27	27

Table 4 shows the degree of importance given to the mathematical notions necessary for the understanding of each of the basic notions of electromagnetism in physics class by teachers in high schools and colleges. The interest rate that teachers give to mathematical concepts to make the teaching of electromagnetism understandable is around 50%. Thus, specifically, we note the results:

- **The electric field**

- Concerning the concept of vector, we record an average of 78% response (Very important + Important) against 20% response (Unimportant + No response). These results indicate that the majority of teachers (nearly 80%) attach great importance to the concept of vector; thus, in their teaching they insist on the characteristics of this notion. About 20% of these teachers believe that teaching this mathematical notion is devolved to mathematics teachers. This is detrimental to a large number of students who have difficulty in mastering and using the concept of vector for a better representation of the electric field vector.
- For the concept of superposition of the vectors used within the framework of the interaction of the dipole electric charges, we record a response rate (Very important + Important) in the order of 48% with only 2 components out of 10 which have a rate average of 50%; This shows that teachers insist less when teaching on this important notion for representing and characterizing the resultant of interactions of electric charges. This insufficiency at the level of teachers constitutes for the students real difficulties concerning the mastery and the use of the concept of superposition of the vectors for a better representation of the resulting electric field vector.

- Concerning the notion of scalar product, we note a response rate of 51% (Very important + Important) against a response rate of over 40% (Not important + No response) for the importance that teachers give in class from physics to this notion; this rate of 40% of teachers who do not insist on this notion during their teaching is detrimental because it further amplifies the difficulties associated with the use of the notion of scalar product among students.

- **The magnetic field**

- Concerning the concept of vector, an average of 63% of response (Very important + Important). These results show that the characteristics of this mathematical notion are fairly mastered by the pupils ; which should in principle allow the pupils to better represent the electric field.
- However for the concept of superposition of the vectors used within the framework of the interaction of the dipole electric charges, the response rate (Very important + Important) is in the order of 48% with only 2/10 which have a rate at -over 50%; which demonstrates the real difficulties of students in appropriating mathematical notions for the contextualization of the notion of electromagnetism in physics class.
- Concerning the notion of cross product, we note an average of 43% of response (Very important + Important); which demonstrates that students' knowledge of the dot product is insufficient for their best use in physics activities.

- **The Earth's magnetic field**

- Concerning the concept of vector, an average of 63% of response (Very important + Important). These results show that the characteristics of this mathematical notion are fairly mastered by the pupils ; which should in principle allow the pupils to better represent the electric field.

- **Electromagnetic induction**

- Concerning the notion of scalar product, we note an average of 51% of response (Very important + Important); which shows that students' knowledge of the dot product is acceptable for their best use in physics activities.

- **Self-induction**

- Regarding the notion of differential equation, an average of 62% response (Very important + Important). These results show that the characteristics of this mathematical notion are fairly mastered by the pupils ; which should in principle allow the pupils to better represent the electric field.
- **DISCUSSION**
- Regarding high school and middle school teachers, we recorded that a large part of the latter do not deem it necessary to draw the students' attention to certain objects of observation of the founding concepts. This is explained by the fact that they ignore the importance of observation objects from the founding notions in the interpretation of electromagnetic phenomena. By not insisting on a large number of objects of observation of the founding notions of electromagnetism in classroom practices, teachers in high schools and colleges do not strengthen the understanding of the phenomena they study with the students, and still less their assimilation. Consequently, the weak mobilization of the founding concepts in class activities constitutes a major handicap for the pupils.
- We believe that this proportion of high school and middle school teachers should be taken into account by raising awareness in order to minimize the qualified rates of (Not Important + without indication of the teacher).
- We noted the low rates of the percentages of teachers granted to the qualified importance levels of (Very important + Important) of the mathematical notions used. We have noted that a good majority of high school teachers have difficulty identifying the objects of observation that characterize the mathematical concepts used. These low percentages of teachers granted to the qualified levels of (Very Important + Important) could probably be explained by the fact that the reform of modern mathematics to prepare the bases of university education introduced

concepts such as the concept of vector to three different places of teaching: college geometry, linear algebra and physics; and therefore three types of vectors: geometric vector, algebraic vector and physical vectors. The different physical vectors correspond to distinct mathematical definitions in the formal theory of linear algebra (we speak of: bound vector, sliding vector, axial vector) (Dorier, 1990). The difficulties in characterizing these three types of vectors on the one hand, and the opposing approaches (Induction / Induction) (Lerouge, 2000; Malafosse et al, 2000) between the framework of mathematics and that of physics on the other hand, constitute sources of difficulties for teachers. Teaching / learning difficulties are generally linked to difficulties in using cognitive and metacognitive strategies and in making good use of certain transversal skills (Salin, 2007). The results obtained confirm the fact that during teaching, teachers rarely attract students' attention if a particular object of observation of the different mathematical concepts used to give meaning to the founding concepts is important or if it will be submitted. to an evaluation.

- From the perspective of this work, our results are interesting because they reinforce the analyzes prior to the development of teaching / learning sequences of the notion of electromagnetism in physics class. This analysis of the difficulties linked to the founding notions of electromagnetism and to those used in mathematics will now allow us to formulate a certain number of proposals in terms of teaching strategy.
- We observed during this study that the conceptualization of the notion of electromagnetism in secondary school encounters several obstacles, the lack of characterization of the founding concepts and mobilized in mathematics, the lack of competence in mathematics of the students, as well as the lack of materials laboratory for the achievement of effective teaching / learning in physics class are all factors that handicap both students and teachers in the accomplishment of their task. The main problem for the physics teacher is the lack of continuing education and the lack of cooperation with his math colleague. It is necessary for the latter to participate in seminars on transdisciplinary approaches while respecting the specificity of each discipline (Maingain et al, 2002).

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