Revista Brasileira de Ensino de Ciência e Tecnologia
ISSN: 1982-873X

https://periodicos.utfpr.edu.br/rbect

Physics in the human body: a thematic approach in teaching electromagnetism

Vinicius Pereira dos Anjos
viniciusanjo1@gmail.com
0000-0001-8066-2714
Universidade Tecnológica Federal do Paraná, Curitiba, Paraná, Brasil.

Rita Zanlorensi Visneck Costa
ritazvc@gmail.com
0000-0001-9882-7003
Universidade Tecnológica Federal do Paraná, Curitiba, Paraná, Brasil.

Katia Elisa Prus Pinho
katiaprus35@gmail.com
0000-0002-3542-9283
Universidade Tecnológica Federal do Paraná, Curitiba, Paraná, Brasil.

Noemi Sutil
noemisutil@utfpr.edu.br
0000-0003-3095-3999
Universidade Tecnológica Federal do Paraná, Curitiba, Paraná, Brasil.

ABSTRACT

In a context of controversies on curricular compositions in Science Education, thematic approaches and their potential concerning the link to contextual aspects underlying the educational action and the interrelation between the areas of knowledge are highlighted. Pertinent to this panorama, this work analyzed the perceptions and relations established by students in a thematic approach, involving educational material and activities on the human body in association with electromagnetism. In this research, qualitative and quantitative aspects were concatenated, aggregating the participation of students from the 3rd grade of high school at a public institution in the city of Curitiba, the state of Paraná, with data constituted through questionnaires. The propositions of interpretations involved assumptions of Content Analysis and descriptive statistics and covered two axes: perceptions about curriculum compositions and learning, and the relations involving Physics contents associated with the human body. Through the data collected in the classroom intervention, evidence of motivation and the correlation with learning aspects were evidenced. It was also investigated the link between Physics content and other areas of knowledge involving the subject. In this context, it is worth highlighting the feasibility of thematic approaches for high school in terms of the potential for learning and attributing meaning and significance to curricular compositions.

KEYWORDS: Physics Teaching. Thematic Approach. Human Body. Eletromagnetism.

INTRODUCTION

Physics decontextualized from reality and only related to applied mathematics composes the perceptions of students, which report on curriculum compositions and learning. In reference to this scenario, Physics teaching and learning processes that provide the attribution of meaning and significance to the student are required.

Pertinent to this situation, in this work, the thematic approach referring to the human body in association with electromagnetism is highlighted, with the proposal of material and educational activities, considering the three pedagogical moments (3MP). The potential for contextualization and articulation between areas of knowledge related to learning is emphasized, delineated in terms of motivation and the relations between the contents.

Referring to these productions, the aim is to analyze the perceptions and relations established by students in the 3rd grade of high school in a public institution in the city of Curitiba, in the state of Paraná. The interpretation propositions about these perceptions and relations report the appreciation of the students' expressions in two sets of questionnaires (A and B), involving analytical procedures inherent to descriptive statistics and content analysis. The perceptions about curricular compositions and learning and the relations involving Physics contents related to the human body are evidenced.

THEORETICAL REFERENCE

In reference to curricular compositions, Delizoicov, Angotti, and Pernambuco (2002) show the dependence of teachers on books and handouts in their didactic action. From this issue, the demand for overcoming the traditional way of approaching content is highlighted. With regard to this situation, a school curriculum is demanded that provides a contextualization and the attribution of meaning and significance to the student (HALMENSCHLAGER, 2011; HALMENSCHLAGER; DELIZOICOV, 2017).

Within educational institutions immersed in social contexts, the curriculum takes on a historical-social character and commitment. In this perspective, it is important to approach contemporary science and aspects related to its development in the classroom (SILVA; ARENGHI; LINO, 2013). Pertinent to this outline, it alludes to the articulation between domains of knowledge, inherent to scientific research, highlighting new areas that have been established over the last few years, such as Medical Physics, Biotechnology, Bioengineering, Econophysics and Computational Physics (KLIPPEL, 2012; SANTOS, 2018). In this direction, the fragmentation in Physics, Chemistry and Biology is opposed, with regard to the approach to Nature Sciences in High School.

This chaining is related to the thematic approach, referring to a curricular perspective in which the contents to be taught in a subject are guided in relation to a theme (DELIZOICOV; ANGOTTI; PERNAMBUCO, 2002). This approach provides a broader understanding of a particular subject (AUTH, 2015). It is worth mentioning the reservation presented by Strieder, Watanabe-Caramello, and Gehlen (2012) about not restricting the thematic approach to the perspective of Paulo Freire's propositions, also referring to other theoretical currents. In the thematic aspect, the relationships established between the contents of the educational activities and the students' experiential contexts are highlighted, adding the link between different fields and perspectives (STRIEDER *et al*., 2011; MUNDIM; SANTOS, 2012); it refers to the contextualization and articulation between the areas of knowledge.

Relevant to the thematic approach, the composition of the repertoire of establishing relationships regarding contextual aspects and various domains of knowledge is highlighted. In these terms, we allude to the interrelationship between new contents and other knowledge that constitutes the subject's cognitive structure, in reference to meaningful learning. In the scope of this aspect, in reference to motivational aspects, the subject's availability to establish relations between knowledge is emphasized (AUSUBEL; NOVAK; HANESIAN, 1980).

Under these considerations, the thematic approach to the 3MP is consistent: initial problematization; knowledge organization; and application of knowledge. Regarding the initial problematization, the identification of previous experiences and the proposition of situations to be analyzed are emphasized. The recognition of different perspectives and the consolidation of affinities with other disciplines and mastery of knowledge refer to the organization of knowledge. The application of knowledge provides the understanding of problematic aspects from the perspective of the content addressed in educational activities and its extrapolation to discernments in other situations that contribute to these concepts (DELIZOICOV; ANGOTTI; PERNAMBUCO, 2002; KLIPPEL, 2012).

These potentialities of contextualization and articulation between the domains of knowledge, allocated in the scope of the thematic approach, to the study of the human body, are concatenated. Since the beginning of time, man has sought to know himself and his own body. Different perspectives and philosophies accompany different peoples and cultures regarding this theme. At the end of the Middle Ages, the human body began to be studied rationally, reducing the concept of the sacred (MORAES; GUIZZETTI, 2016). Currently, there are several fields of science that study it, such as Psychology, Anthropology, Sociology and Biological Sciences.

In relation to these aspects, in the 3rd grade of high school, in which classes on electromagnetism are commonly taught, the student experiences the age group that comprises the adolescence. According to psychiatrist Maurício Knobel (cited by DELIZOICOV; ANGOTTI; PERNAMBUCO, 2002), one of the characteristics of adolescents (considered in the Normal Adolescence Syndrome) refers to the understanding of themselves and their identity. Pertinent to these circumstances, Delizoicov, Angotti, and Pernambuco (2002) suggest that in Natural Sciences, including Physics, didactic approaches can encompass bodily changes.

In this research, the theme of the human body and electromagnetism is articulated, reconciling the 3MP, with the objective of developing and evaluating an educational proposal to approach electromagnetism with an association between Physics and the human body. The linking of aspects of electromagnetism to the theme refers to teacher compositions associated with the thematic approach, as noted by Silva *et al*. (2019). The human body is a theme that allows students to contextualize it, covering the analysis of contemporary and everyday technologies and their development. It demands the articulation between areas of knowledge, not restricted to physiological aspects, from the perspective of Biology, also incorporating the view of Physics. In this direction, it is possible to compose the repertoire of establishing relationships in reference to learning and the motivation to learn. In this specific case, the urgency of identifying prior knowledge on the subject is noteworthy, particularly considering the approach to the human body in the subjects of Science in Elementary School and Biology in High School.

METHODOLOGY

This research involves qualitative (FLICK, 2009) and quantitative (MOREIRA, 2011) aspects and covers the development of material (educational product) and educational activities (GIL, 2019) related to the association between the human body and electromagnetism. The educational activities were developed in the first half of 2019, in a class of 30 students from the 3rd grade of high school in a public institution in Curitiba, Paraná, in a to Chapter 4 of the educational product (composed of six chapters).

Pertaining to these actions, two sets of questionnaires were investigated, with open and closed questions, answered by the students: before the educational activities (Questionnaire A) and after these activities (Questionnaire B). These procedures cover Content Analysis assumptions (BARDIN, 2011) and descriptive statistics (MOREIRA, 2011).

This research, with a favorable opinion from the Research Ethics Committee involving Human Beings (CEP) of the Federal Technological University of Paraná (UTFPR), obtained a Certificate of Presentation for Ethical Appreciation (CAAE) through the number 08933319.7.0000.5547. The actions and analysis performed refer to authorization documents made possible by the subjects involved in the study, after prior exposure of the research objectives and procedures to the students and their guardians.

EDUCATIONAL PRODUCT

Chart 1 presents the chapters of the educational product and their respective subjects.

Chart 1 – Educational product organization

Chapter	Subject
1	The origin of everything
2	Neurons: potential difference and electric current
3	Electric shock
4	Cell membranes =capacitors
5	Brain magnetic field
6	Electrical activity in the eyes and skin

Source: Authors (2019).

For the elaboration of the educational product, aimed at high school teachers and students, bibliographic materials on Physics, Biophysics, Anatomy, and Physiology were analyzed. The texts cover, among others, the concepts of potential difference, electromotive force, electric current, Joule effect, and electric charge. They express associations between physical concepts and everyday aspects, the human body, and contemporary health technologies. At the beginning of each chapter, the knowledge about Human Anatomy and Physiology and activities for the student to identify aspects of the organs of the human body are highlighted.

Chapter 1 (The Origin of Everything) presents the introduction and electromagnetism. It covers historical aspects of the constitution of matter and the atom from Thales to Faraday. It identifies elements that define electrostatics, electrodynamics, and electromagnetism, alluding to everyday phenomena and equipment. In this follow-up, the association of the human body stands out, for example, in cell communication by electrical signals and in the potential difference of a cell membrane. It expands the links to health technologies, highlighting, for example, magnetic resonance imaging and the pacemaker for the heart. Furthermore, it explains particularities in the history of the study of Biophysics and, more specifically, of Bioelectromagnetism.

In chapter 2 (Neurons: potential and electrical current difference) the anatomy and physiology of a neuron, its function, and characteristics are shown. The neuron is associated with a conducting wire and the Myelin Sheath with a dielectric. To explain the potential difference, it refers to the sodium and potassium pump. Considering the amount of electrical charge that the pump carries in a neuron, the electrical current in it is calculated. It links the definition of electrical current to synapses and communication in neural tissue. The interrelation between cell functioning and diseases is also highlighted.

At the beginning of chapter 3 (Electric shock), the definition and classification of static and dynamic shocks and atmospheric discharges are emphasized. The distinctions between direct and alternating current are pointed out. The analysis of the intensity of the electric current and the effects caused on the human body are explained. Throughout the text, the electrical resistance is outlined in reference to the skin, blood, and muscles. Referring to possible burns related to electrical shock in the human body, the Joule effect is presented. The considerations extend to the safety and health recommendations pertaining to the care of the person victim of electric shock, including contribution to residential electrical installations. In the proposed studies, the effects of electromagnetic fields on the human body stood out.

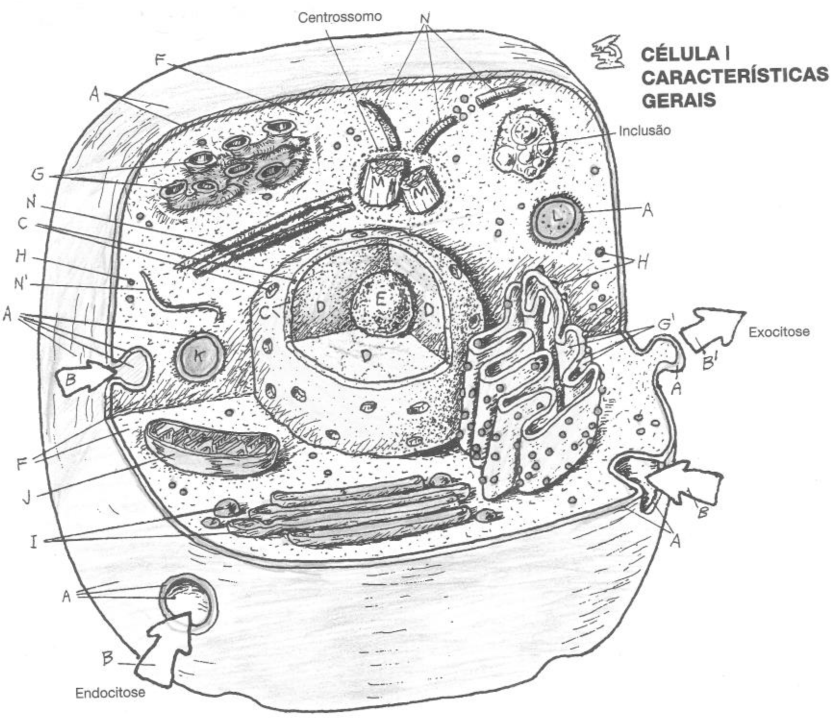
Chapter 4 (Cell membranes = capacitors) begins with an explanation of the animal cell and the function of the plasma membrane. In Figure 1, the initial part of that chapter is presented with expressions alluding to anatomy and physiology.

Figure 1 – Chapter 4 – Initial part

4 *CELL MEMBRANES = CAPACITORS*

There is a small and fundamental part of our body that collects substances, recycles and releases them, called the cell (Figure 1). Each cell takes on a specialized function. They can be linked to each other, for example, forming tissues, or free in the body, such as red blood cells. Its basic structure is composed of cytoplasm and organelles, a nucleus, and a membrane that surrounds it (MÜNCHEN, 2009). The cell membrane allows the entry (endocytosis) and exit (exocytosis) of materials to the interior and exterior of the cell (as shown in Figure 1) (KAPIT; ELSON, 2018).

Figure 1: General characteristics of the cell: Cell membrane (A): Endocytosis process (B), Exocytosis process (B1), Nuclear membrane (C), Nucleoplasm (D), Nucleolus (E), Cytoplasm (F), Smooth Endoplasmic Reticulum (G) and Rugoso (G1), Ribosome (H), Golgi Complex (I), Mitochondria (J), Vacuole (K), Lysosome (L), Centriole (M), Microtubule (N), Microfilament (N1).



Source: KAPIT; ELSON (2018).

Source: Authors (2019).

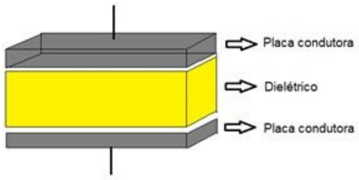
Then, the concept of capacitors and their daily application is emphasized. Among the examples, there is the defibrillator, which contains the capacitor in its circuit, which is used when the pumping of blood from the heart happens at an atypical frequency. Figure 2 below expresses these correlations in educational output.

Figure 2 – Chapter 4 – Capacitor and defibrillator

Capacitors (Figure 2) are devices that accumulate energy to be released little by little (BISCUOLA; BÔAS; DOCA, 2010). Capacitors are found in camera flash, remote controls, radio, etc. Every potential difference U between plates at a distance d generates an electric field E.

$$U = E * d$$

Figure 2: Capacitor with dielectric.



Source: Authors (2019).

In a circuit, the battery connected to the capacitor generates the potential difference (d.d.p.). In the case of the brain, the human body's own energy generates a potential difference to keep the neuron at rest and accumulate energy.

$$Q = CU$$

C is the conductor's capacity to store charges and we call it **capacitance**, U a sd. and Q the stored electrical charge. It depends on its geometric characteristics and the environment in which it finds itself.

Analyzing a capacitor, the larger the area of the plates, the more charges can be accumulated, but the smaller the distance, the more ideal the capacitor will be. Then, between the plates a dielectric is placed.

$$C = \varepsilon * \frac{A}{d}$$

The capacitance unit is:

$$farad = \frac{coulomb}{volt}$$

Where ε is the electrical permittivity of the material, *A* is the plate area and *d* is the distance between the capacitor plates.

The human heart pumps blood throughout the body at a certain rate. It pumps 300 to 400 liters of blood per hour. The impulses originate in two small nodules, located one in the wall of the right atrium: the sinus node triggers 70 to 80 heart beats per minute (bpm) and another atrioventricular node with a frequency of 40 to 60 bpm (MÜNCHEN, 2009). When this pumping occurs at an atypical or altered frequency, it is called fibrillation or cardiac arrhythmia, the ventricular muscle does not contract in a coordinated way, which is important for the heart's pumping process. To charge and discharge electrical charges in the heart muscle fibers or in the chest wall, a defibrillator is used, it contains a capacitor (GUYTON; HALL, 2011).

The accumulated energy of a capacitor is:

$$E_{pot} = \frac{CU^2}{2}$$

Source: Authors (2019).

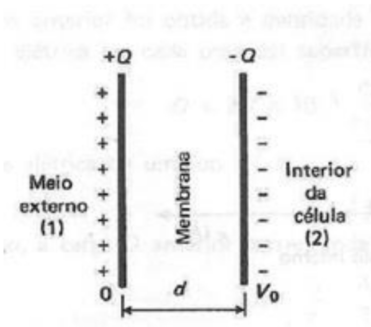
The cells are associated with a capacitor with a dielectric, specifying that inside and outside the cells there is a difference in electrical charges (difference in potential). As an example, using the thickness of the membrane and its area, the value of cell capacitance per unit area is calculated. Finally, an example of capacitance measurement in Purkinje fibers is presented. In Figure 3, below, the final elements of the chapter are presented.

Figure 3 – Chapter 4 – Capacitor and cells

Axons (extensions of neurons that conduct electrical impulses) can be, in a simplified way, considered capacitors. It is possible to calculate the electrical charge stored in the axon knowing its size and the potential difference to which it is subject (ENEM HQ, 2017).

The cells can be associated with a capacitor with a dielectric, as shown in the diagram in Figure 3. Both the interior and the exterior of a cell are filled with well-diluted saline solutions, decomposed into ions. These conductive saline solutions are separated by an insulating layer: the membrane (OKUNO; CALDAS; CHOW, 1982).

Figure 3: Cell membrane seen as parallel plate capacitor.



Source: OKUNO; CALDAS; CHOW (1982).

The thickness of a membrane is about 80 Å and its area is 6* 〖10〗 ^(-2) m². Calculating the cell capacitance per unit area (where the characteristic value for the membrane electrical permittivity constant is ε≅10ε_0, that is, 10 times the electrical permittivity of a vacuum):

$$C = \frac{\varepsilon}{Ad}$$

$$\frac{C}{A} = \frac{\varepsilon}{d} = \frac{10 * 8{,}85 * 10^{-12}}{80 * 10^{-10}} = 1{,}1 * 10^{-2} F/m^2$$

In Purkinje fibers (located in the heart), capacitances of up to 12 μF/cm² were measured (OKUNO; CALDAS; CHOW, 1982; GARCIA, 2002).

Source: Authors (2019).

In Chapter 5 (Magnetic Field of the Brain), concepts of magnetism are emphasized. In the beginning, the anatomy of the human brain and its structures are presented and the interest in the study of this organ by scientists and the method of magnetoencephalography (MEG) in research and examinations is underlined. From the presentation of this exam, it is highlighted that electric currents generate magnetic fields (electric pulses transmitted by the brain produce the magnetic fields detected by the MEG). Functional magnetic resonance is also evidenced, explaining the production of images in the exam and the order of magnitude of resolution. This chapter approaches a remarkable event in the history of science: Oersted's (1820) finding of the deviation in the needle with the approximation of an electric wire covered by the electric current. In reference to this content, an example is the calculation of the magnitude of a magnetic field detected by the MEG due to electrical impulses from the brain. At the end of the chapter, researches related to the treatment of neurological diseases involving magnetic nanoparticles are discussed.

Chapter 6 (Electrical Activity in the Eye and Skin) covers vision, eye function, and imaging (from the entry of light rays into the pupil until electrical impulses reach the brain). The electro-oculogram exam is presented, which involves the detection of a stable electric potential field (corneoretinal potential), for the study of eye movement. Throughout the text, it is mentioned that diseases such as cataracts and glaucoma can be diagnosed through a test called an electroretinogram, which detects electromagnetic fields in the retina. The concepts of conductance and electrical resistance were approached with reference to the skin. It should be noted that such properties (such as potential difference between two points) of the skin help, for example, in the investigation of psychopathologies or detection of lies. This chapter presents information on the development of science and technology and its implications for human health and safety.

EDUCATIONAL ACTIVITIES AND QUESTIONNAIRES

The educational activities developed with a class of 30 students from the 3rd grade of high school, according to the 3MP, involved studies on cell membranes and their association with capacitors, with the study of chapter 4 from the educational product in the classroom, in two hours-class (time allowed by the subject teacher). The option for chapter 4 is due to the need to link these actions with the teaching plan of the discipline of Physics of the institution where the investigation was carried out. In agreement with the regent teacher, the capacitors theme was the one that is most accurate to the group's planning, as the students had already studied contents, such as electrical charge, potential difference and potential energy, which would be prerequisites.

The students' answers in Questionnaire A (Chart 2), before the educational activities, provided, associated with discursive interactions involving professors and students, elements to the initial problematization. This document also made it possible to identify the students' prior knowledge and social and idiosyncratic aspects with regard to contextualization perspectives, articulation between areas of knowledge and expansion of the repertoire of establishing relationships involving Physics contents. The questions of that document are presented below:

1. What is your motivation for studying Physics? Check your level of motivation in the table below, with 1 (very low), 2 (low), 3 (medium), 4 (high), 5 (very high). Comment on the lines below.
2. Can you identify Physics in your every day life? Justify your answer.
3. Explain the concept of capacitors.

4. Where do you find capacitors in your every day life?
5. Is it possible to study Physics with the human body? Justify.
6. Is it possible to establish any relation between capacitors and the human body?
7. Does a physician, a physiotherapist, a biologist need to learn Physics? If so, could you give an example of where to find Physics in these professions or what they study?

In reference to the 2nd MP (knowledge organization), involving discursive interactions between professors and students, contents from previous years were reviewed, such as electric charge, electric field, and electric potential, relevant to the theme, and highlighted relations with aspects of the experiential reality of the involved, with an emphasis on the associations between cell membranes and capacitors (chapter 4).

In the 3rd MP (knowledge application), opportunities were expanded for students to establish relations involving the contents covered and expanded to other situations. At the time, the students answered Questionnaire B (Chart 3). The issues in this document are highlighted below.

1. Is it interesting to study Physics in the human body? Justify.
2. Material evaluation. Mark a rating level for each item, being 1 (very low), 2 (low), 3 (medium), 4 (high), 5 (very high).
3. Does the material bring Physics in a more interesting way when it relates to the human body?
4. Is the material in an accessible and not tiring language?
5. Are there any comments you would like to make about the material, such as critics or suggestions?
6. Is it possible to establish any relation between capacitors and the human body?
7. Check the level of your understanding of capacitors when studied together with the human body in the table below, being 1 (very low), 2 (low), 3 (medium), 4 (high), 5 (very high). Is it easier to understand capacitors this way?
8. Explain the concept of capacitors.
9. Do you believe it is possible to relate Physics to other aspects of the human body beyond what was studied in class? If so, give examples.

DATA ANALYSIS ELEMENTS

The propositions of explicit interpretations refer to the analysis of questionnaires A and B. With regard to closed questions, descriptive statistics was used, showing the arithmetic mean to represent the results (MOREIRA, 2011). For the analysis of qualitative questions, the assumptions of Content Analysis were reported (BARDIN, 2011). For this purpose, keywords were selected, in the students' speeches, that denote a relationship with the theme of the question, which were categorized into different groups, emphasizing the frequency of occurrence.

Pertinent to the qualitative analysis, in Questionnaire A, the references motivation, contextualization, specific content and theme are established, as shown in Chart 2, concerning the student's discourse and the researcher's interpretation.

Chart 2 – Data analysis elements - Questionnaire A

Reference	Question	Classification
Motivation	What is your motivation to study Physics? [...] Comment [...].	Very low - Low
		Medium
		High – Very high
Context	Can you identify physics in your daily life? Justify your answer.	Yes
		No
Specific Content	Explain the concept of capacitors.	Involves energy storage - adequate
		Didn't know / Didn't answer
		Off topic
Specific Content	Where do you find capacitors in your every day?	Appropriate answer / idea
		Don't know / inadequate answer / no answer
Theme	Is it possible to study Physics with the human body? Justify.	Yes
		No
		Didn't answer
Theme	Does a physician, a physiotherapist, a biologist, need to study Physics? If so, could you give n example of where to find Physics in these professions or what they study?	Yes
		No / Didn't answer

Source: Authors (2019).

In Questionnaire B, the motivation, material evaluation, specific content and contextualization are emphasized, as shown in Chart 3, concerning the student's discourse and the researcher's interpretation.

Chart 3 – Data analysis elements - Questionnaire B

Reference	Question	Classification
Motivation	Is it interesting to study Physics in the human body? Justify.	Yes
		No
Material evaluation	Are there any comments you would like to make about the material, a criticism or suggestion?	Negative aspect
		Positive aspect
		Neutral / didn’t answer
Specific content	Explain the concept of capacitors.	Involves energy storage - adequate
		Didn’t know / didn’t answer
		Off topic
Context	Do you believe it is possible to relate Physics to other aspects of the human body other than what was studied in class? If so, give examples.	Yes
		No

Source: Authors (2019).

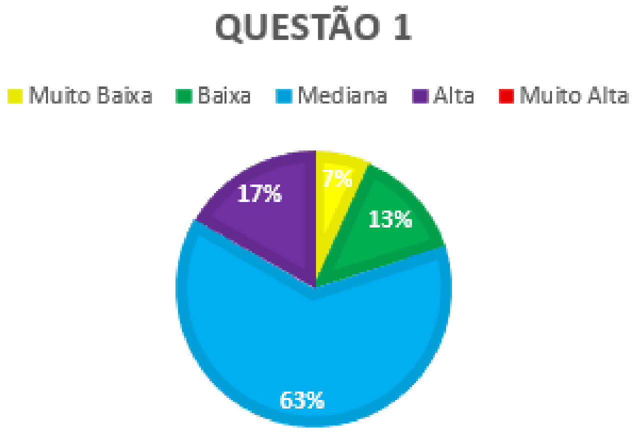
DATA ANALYSIS

The interpretation of propositions comprehends two analytical axes: perceptions about curricular compositions and learning; relations involving Physics contents in reference to associations with the human body. Presenting exemplary expressions, students are designated by the letter E, followed by a number (E1 to E6).

Initially, the analysis of answers from Questionnaire A, involving 30 students, is highlighted. In allusion to these perceptions, according to the data obtained, 63% of the students rated themselves as having average motivation in the first question (“What is your motivation to study Physics?”); the justification relating to the lack of affinity with the discipline for the negative statements about motivation stood out, for instance, the answer of student E1: "I have no affinity with the subject, I prefer Biological Sciences", or student E2: "I don't really like Exact Sciences”. Otherwise, several students indicated the relevance of Physics in the curriculum and its link with their every day lives, linking motivational and learning aspects, referring to assumptions made by Ausubel, Novak, and Hanesian (1980).

As it can be seen in Figure 4, 13% of students expressed low motivation and 7% very low; according to them, there is no interest or appreciation for hysics. The other students showed high (17%) and medium (63%) motivation. Referring to this, the students highlighted their curiosity to understand the world, their affinity with laboratory activities, and the importance of appropriating knowledge, for example, in student E3's answer: "My motivation is that physical phenomena are part of of our lives and the explanation, arriving at a spectacular answer”. It is inferred about the motivation associated with the link between Physics contents and the subjects' experiential aspects, regarding the contextualization, in line with the assertions of Strieder *et al*. (2011) and Mundim and Santos (2012).

Figure 4 – Frequency of answers to question 1 (Questionnaire A): "What is your motivation to study Physics?"



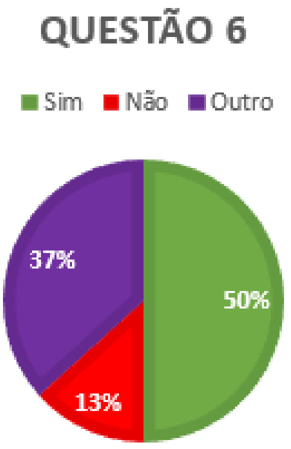
Source: Authors (2019).

Question 2 (“Can you identify Physics in your every day?”) evidenced the contextualization. Most students (93%) were able to identify physical phenomena in daily life, such as, for example, in student E2's answer: “(...) playing basketball we use strength, distance and weight, etc.”. Referring to Chart 1, the answers obtained in the justifications refer, in big part, to contents taught in the 1st grade of High School (mechanics). There were also students who expressed responses involving light and technology.

About the specific content, in question 3 ("Explain the concept of capacitors"), it was found that 80% of the students didn't know how to answer properly, writing that they don't know what a capacitor is or answers such as the one exemplified by student E4: " They are energy (power) amplifiers”, with an incorrect concept. In question number 4 (“Where do you find capacitors in your every day?”), most didn't give examples.

In question 5 (“Is it possible to study Physics with the human body?”), there was no negative answer. Excluding abstentions, 28 students (93%) answered affirmatively and it was noticed that they identified phenomena related to mechanics, such as force and movement, and thermology. In question 6 (“Is it possible to establish any relation between capacitors and the human body?”), half of the students (50%) answered positively. Due to the large number of students who answered “I don't know” (37%), this data was taken into account. These results are presented in Figure 5, below.

Figure 5 – Frequency of responses to question 6 (Questionnaire A): "Is it possible to establish any relation between capacitors and the human body?"



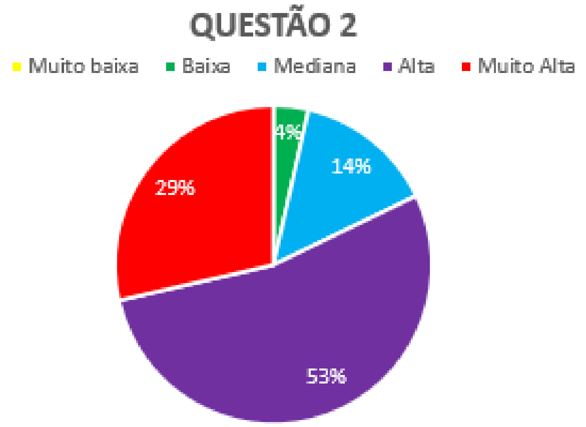
Source: Authors (2019).

“Does a physician, a physiotherapist, a biologist need to it is possible Physics in these professions or what they study?” was the last question in Questionnaire A. Most students (83%) highlighted the importance of Physics in these professions, exemplifying that physicians need to know about optics or thermology, a biologist needs to know mechanics to study the movements of animals, etc., as for example in student E5's answer: “Physician: body temperature and pressure. Physiotherapist: movement of muscles. Biologist: care for animals and their environments”. On the other hand, 10% of students stated that these professionals do not need to study Physics.

These analyses are associated with propositions of interpretations relevant to the answers in Questionnaire B, covering 30 students, after the educational activities. In the scope of the thematic approach linked to the human body, in the answers to question 1 (“Is it interesting to study Physics in the human body?”), 93% of the students expressed a positive perception of this “new” perspective. They pointed out that the study of this theme referred to something unusual in the study of Physics, with a predominance in Biology, as in the following expressions. “It helps us to have a better understanding of our body” (E3). “To learn new things” (E4). “(...) improves their physical and biological knowledge” (E5). Motivational aspects provided by the association of Physics content to the theme are inferred, in a context involving students with interests related to contextualization and some students disaffected to the discipline (according to the analysis of question 1 of Questionnaire A). In reference to these aspects, the considerations of Mundim and Santos (2012, p. 800) are correlated, regarding the urgency of providing students with “[...] to understand the meaning of scientific knowledge for life and for social relations that are established in the course of time and societies”.

Regarding educational material, in question 2 (Chart 3), 53% of students rated the level of interest as high and 29% as very high. The results are shown in Figure 6, below.

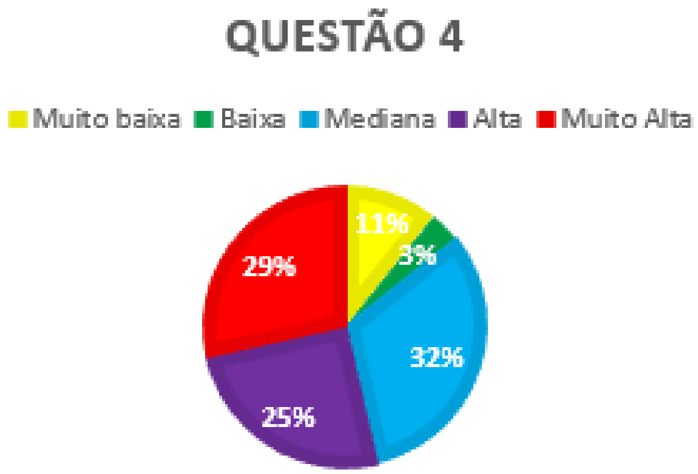
Figure 6 – Frequency of responses to question 2 (Questionnaire B): Evaluation of the material



Source: Authors (2019).

In question 4 (“Is the material in an accessible and not tiring language?”), 11% classified it as very low and 3% as low, showing a higher percentage of positive perceptions about accessibility to the proposed discussions. The data are represented in Figure 7, below.

Figure 7 – Frequency of responses to question 4 (Questionnaire B): "Is the material in an accessible and not tiring language?"



Source: Authors (2019).

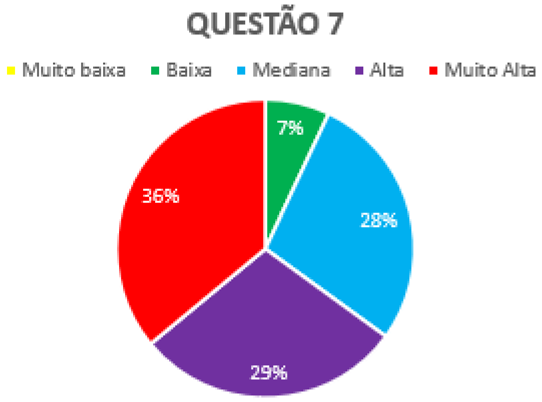
Among the suggestions of the students, the expansion of playful aspects are noteworthy, considered in the review of the educational product. On these expressions, it is worth signalizing the relevance of analyses carried out by students on motivation and learning in relation to their training experiences.

Questions 6 and 7 of Questionnaire B indicated perceptions about thematic approach and learning, in reference to the specific content, and enabled analyses linked to questions 5 and 6 of Questionnaire A.

In question 6 (“Is it possible to establish any relation between capacitors and the human body?”), it was verified that 96% of the students affirmed positively, as in the example of student E6: “(...) temperature, beats, and energy of the Human

Body". In question 7 ("Is it easier to understand capacitors this way?"), it is inferred, regarding the representation in Figure 8, that most students perceived aspects of learning combined with this type of approach that establishes a relation between Physics and the human body (36% rated it as very high and 29% rated it high).

Figure 8 – Frequency of responses to question 7 (Question B): "Is it easier to understand capacitors this way?"



Source: Authors (2019).

Questions 8 and 9 of Questionnaire B (Chart 3) report the relations established by students involving Physics contents in reference to the theme and allow correlations with questions 3 and 4 of Questionnaire A.

In question 8 ("Explain the concept of capacitors"), it was found that 86% of students responded coherently, evidencing the idea of energy storage. It is inferred about evidence of learning, revealing the results of questions 3 and 4 of Questionnaire A (Table 2), in which gaps were found in terms of fundamentals on the subject presented.

Returning to Physics in the human body, in question 9 ("Do you believe it is possible to relate Physics to other aspects of the human body besides what was studied in class? If yes, give examples"), only 14% of students said it was not possible to establish such a relationship. Regarding the students who affirmed positively, they presented examples that related the contents of mechanics, such as force and speed, and thermology (temperature and thermal energy); the word energy, in allusion to a broader concept, was also associated by students.

In answer 5 of Questionnaire A, prior to the actions developed, it was noted that until then the students were able to identify Physics in their daily lives, but not in the human body. After the educational activities, in Questionnaire B, question 9, the students explained examples of Physics in the human body beyond those covered in the classroom. It is identified, in reference to these cases, the expansion of the repertoire of establishing relations, in allusion to the guidelines of Ausubel, Novak, and Hanesian (1980), attributing greater complexity to previously studied contents with the association to the theme, in line with propositions by Delizoicov, Angotti and Pernambuco (2002), Strieder *et al*. (2011), Mundim and Santos (2012) and Silva *et al*. (2019).

FINAL CONSIDERATIONS

In this research, in terms of the thematic approach associated with contextualization and articulation between different areas of knowledge, an educational proposal for the study of electromagnetism was developed. Material and educational activities were elaborated, showing the relationship between electrical and magnetic phenomena and the human body. Based on the analysis performed (Descriptive Statistics and Content Analysis), from data constituted by means of questionnaires, the potential of this proposal for the motivation and learning of students is highlighted.

Concerning motivational aspects, the expansion of the spectrum of interests is pointed out, including students who identify themselves as non-sympathetic to exact sciences. Relations established between electricity and magnetism and the human body were evidenced by the students with the development of that proposal. The composition and expansion of the repertoire of establishing relations are highlighted, adding different perspectives on contents covered in the discipline of Biology and previous years of Physics.

It is worth mentioning the limitations of the explicit interpretation propositions, referring to the restricted dimensions of the actions undertaken. However, this study is consistent with other investigations on thematic approaches, evidencing the aforementioned potential for motivation, learning, and attribution of meaning and meaning in educational processes in Physics and Science.

FÍSICA NO CORPO HUMANO: UMA ABORDAGEM TEMÁTICA NO ENSINO DO ELETROMAGNETISMO

RESUMO

Em um cenário de controvérsias sobre composições curriculares na Educação em Ciências, evidenciam-se as abordagens temáticas e suas potencialidades concernentes à vinculação a aspectos contextuais subjacentes à ação educativa e à inter-relação entre as áreas de conhecimento. Pertinente a esse panorama, neste trabalho, analisou-se as percepções e relações estabelecidas por estudantes em abordagem temática, envolvendo material e atividades educacionais sobre o corpo humano em associação com o eletromagnetismo. Nesta pesquisa, concatenaram-se aspectos qualitativos e quantitativos, agregando a participação de discentes do 3º ano do Ensino Médio de uma instituição pública da cidade de Curitiba, no estado do Paraná, com dados constituídos por meio de questionários. As proposições de interpretações envolveram pressupostos de Análise de Conteúdo e estatística descritiva e abrangeram dois eixos: percepções sobre as composições curriculares e a aprendizagem, e as relações envolvendo conteúdos de Física associados ao corpo humano. Através dos dados levantados na intervenção em sala de aula, indícios de motivação e correlação com aspectos de aprendizagem foram evidenciados. Averiguou-se, ainda, a vinculação entre conteúdos de Física e de outras áreas de conhecimentos envolvendo a temática. Cabe salientar nesse contexto a viabilidade de abordagens temáticas para o Ensino Médio no que se refere às potencialidades de aprendizagem e de atribuição de sentido e significado às composições curriculares.

PALAVRAS-CHAVE: Ensino de Física. Abordagem temática. Corpo humano. Eletromagnetismo.

REFERENCES

AUSUBEL, D. P.; NOVAK, J. D.; HANESIAN, H. **Psicologia educacional**. Rio de Janeiro: Interamericana, 1980.

AUTH, M. Abordagem temática no ensino médio: decorrências na física e nas ciências da natureza. **Ensino Em Re-Vista**, Uberlândia, v. 22, n. 2, p. 299-309, 2015. Available at: http://www.seer.ufu.br/index.php/emrevista/article/view/34459. Access on: Jul. 20th, 2020.

BARDIN, L. **Análise de conteúdo.** 1. ed. São Paulo: Edições 70, 2011.

BISCUOLA, G. J.; BÔAS, N. V.; DOCA, R. H. **Física: ensino médio.** v. 3. 1. ed. São Paulo: Saraiva, 2010.

DELIZOICOV, D.; ANGOTTI, J. A.; PERNAMBUCO, M. M. **Ensino de ciências:** fundamentos e métodos. 1. ed. São Paulo: Cortez, 2002.

FLICK, U. **Introdução à pesquisa qualitativa.** 3. ed. Porto Alegre: Artmed, 2009.

GARCIA, E. A. C. **Biofísica**. São Paulo: Sarvier, 2002.

GIL, A. C. **Métodos e técnicas de pesquisa social**. 7. ed. São Paulo: Atlas, 2019.

GUYTON, A. C; HALL, J. E. **Tratado de Fisiologia Médica.** 12. ed. Rio de Janeiro: Elsevier, 2011.

HALMENSCHLAGER, K. R. Abordagem temática no ensino de ciências: algumas possibilidades. **Vivências**, Recife, v. 7, p. 10-21, 2011. Available at: http://www2.reitoria.uri.br/~vivencias/Numero_013/artigos/artigos_vivencias_13/n13_01.pdf. Access on: Jul. 26th, 2021.

______.; DELIZOICOV, D. Abordagem temática no ensino de ciências: caracterização de propostas destinadas ao ensino médio. **Alexandria**, Florianópolis, v. 10, n. 2, p. 305-330, 2017. Available at: https://periodicos.ufsc.br/index.php/alexandria/article/view/1982-5153.2017v10n2p305. Access on: Jul. 20th, 2020.

KAPIT, W; ELSON, L. M. **Anatomia – Um livro para colorir.** 4. ed. Rio de Janeiro: Roca, 2018.

KLIPPEL, C. C. **Física do corpo humano:** elaboração de um material didático para o ensino médio. 2012. 251 f. Dissertação (Mestrado em Ensino de Ciências e Matemática) - Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte, 2012. Available at: http://www.biblioteca.pucminas.br/teses/EnCiMat_KlippelCC_1.pdf. Access on: Jul. 20th, 2020.

MORAES, V. R. A.; GUIZZETTI, R. A. Percepções de alunos do terceiro ano do Ensino Médio sobre o corpo humano. **Ciência & Educação**, v. 22, n. 1, p. 253-270, 2016. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-73132016000100253&lng=pt&tlng=pt. Access on: Jul. 20th, 2020.

MOREIRA, M. A. **Metodologias de pesquisa em ensino.** 1. ed. São Paulo: Livraria da Física, 2011.

MÜNCHEN, E. G. **Atlas da anatomia.** Königswinter: H. F. Ullmann, 2009.

MUNDIM, J. V.; SANTOS, W. L. P. Ensino de ciências no ensino fundamental por meio de temas sociocientíficos: análise de uma prática pedagógica com vista à superação do ensino disciplinar. **Ciência & Educação**, v. 18, n. 4, p. 787-802, 2012. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-73132012000400004&lng=pt&tlng=pt. Access on: Jul. 20th, 2020.

OKUNO, E; CALDAS, I. L; CHOW, C. **Física para ciências biológicas e biomédicas.** 1. ed. São Paulo: Harbra & Row do Brasil, 1982.

QG do ENEM. **Bioeletricidade e o Corpo Humano - Física e Biologia | Completo ENEM + 2017**. (1h10m04s). 2017. Available at: https://www.youtube.com/watch?v=hBvrnKXAJlk&t=868s. Access on: Jul. 20th, 2020.

SANTOS, L. R. **A física do olho humano:** uma proposta para o ensino de óptica. 2018. 117 f. Dissertação (Mestrado em Ensino de Ciências e Matemática) - Centro Universitário Franciscano, Santa Maria, 2018. Available at: http://www.tede.universidadefranciscana.edu.br:8080/handle/UFN-BDTD/600. Access on: Apr. 29th, 2020.

SILVA, J. R. N.; ARENGHI, L. E. B.; LINO, A. Por que inserir física moderna e contemporânea no ensino médio? Uma revisão das justificativas dos trabalhos acadêmicos. **Revista Brasileira de Ensino de Ciência e Tecnologia**, Curitiba, v. 6, n. 1, p. 69-83, jan-abr, 2013. Available at:

https://periodicos.utfpr.edu.br/rbect/article/view/1170. Access on: Jul. 20th, 2020.

SILVA, L. F.; TAVARES, S. S.; WATANABE, G.; HALMENSCHLAGER, K. R.; STRIEDER, R. B.; HUNSCHE, S. Elementos da abordagem temática no Ensino Médio: sinalizações para formação de professoras e professores. **Ciência & Educação**, v. 25, n. 1, p. 145-161, 2019. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-73132019000100145&tlng=pt. Access on: Jul. 20th, 2020.

STRIEDER, R. B.; WATANABE-CARAMELLO, G.; HALMENSCHLAGER, K. R.; FEISTEL, A. B.; GEHLEN, S. T. Abordagem de temas na pesquisa em Educação em Ciências pressupostos teóricos-metodológicos. *In:* ENCONTRO NACIONAL DE PESQUISA EM EDUCAÇÃO EM CIÊNCIAS. 8., 2011, Campinas. **Anais** [...]. Campinas: ABRAPEC, 2011. p. s/n. Available at: http://abrapecnet.org.br/atas_enpec/viiienpec/resumos/R0467-1.pdf. Access on: Jul. 20th, 2020.

STRIEDER, R. B.; WATANABE-CARAMELLO, G; GEHLEN, S. T. Abordagem de temas no ensino médio: compreensões de professores de Física. **Ensaio**, v. 14, n. 2, p. 153-169, ago.-nov., 2012. Available at: https://periodicos.ufmg.br/index.php/ensaio/article/view/34664. Access on: Jul. 26th, 2021.

Received: Aug. 31st, 2020.
Approved: Aug. 05th, 2021.
DOI: 10.3895/rbect.v14n3.13098
How to cite: ANJOS, V. P.; COSTA, R. Z. V.; PINHO, K. E. P.; SUTIL, N. Physics in the human body: a thematic approach in teaching electromagnetism. **Brazilian journal of Science teaching and Technology**, Ponta Grossa, v.14, n. 3, p. 1-21, Sep./Dec. 2021. Available at: <https://periodicos.utfpr.edu.br/rbect/article/view/13098>. Access on: XXX.
Mailing address: Vinicius Pereira dos Anjos - viniciusanjo1@gmail.com