MATHEMATICS APPLIED TO THE DISCIPLINE OF ELECTRIC MOTORS: AN EXPERIENCE WITH PROFESSIONAL AND TECHNOLOGICAL EDUCATION

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ABSTRACT

The Postgraduate Course in Professional and Technological Education – DocentEPT is offered by federal institutes and aims to train teachers in the area of professional technical education. It is important to highlight that in the control and industrial processes axis there are courses that work with content that requires special attention in the area of mathematics. Among these courses, the electrical engineering course can be mentioned. In this sense, this study sought to develop an experience of pedagogical intervention in a technical and professional education school. For this purpose, an electrical engineering class was chosen where a questionnaire was applied to verify which content in the area of basic mathematics the students had the most difficulty with. The study was carried out with 18 students who answered five objective questions. The results obtained showed that half of the class had greater difficulty with trigonometry. Given this, a review of the main concepts of trigonometry such as sine, cosine, and tangent was applied. This mathematical knowledge is essential in the technical training of these professionals.

Keywords: Professional and Technological Education. Area of mathematics. Pedagogical Intervention.

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INTRODUCTION

Professional and Technological Education – EPT is subdivided into technological axes, among which we can highlight the control and industrial processes axis, which, in turn, comprises the technical courses in electroelectronics, electronics, mechanics, chemistry, electromechanics, mechatronics, and electrical engineering. The latter has subjects focused on the area of electricity such as electrical circuits, basic electronics, programming language I, electrical controls, electrical maintenance, electric motors, and electrical engineering, among others.

Therefore, according to Porto (2023), the technical course in electrical engineering is of great importance for the industrial development of a country. This is because, according to the author, electrical engineering is present in several sectors of the industrial area, such as telecommunications, electrical maintenance, energy, and maintenance of electrical equipment, among others. A characteristic present in technical courses in the industrial area is the constant use of mathematical calculations to carry out their activities.

Mathematics is a science that is present in the daily lives of human beings and its mastery is important for the development of techniques and instruments for work and the performance of other activities. Therefore, in the field of technical and professional education, mathematics becomes essential for the correct handling of tools, both in the economic aspect and for the safety of individuals. It is also known, according to Palhares (2022), that only 5% of students who finish high school have an adequate performance in the area of Mathematics. Regarding learning in physics, it is also clear that many students have difficulty understanding concepts and formulas.

In view of this, this work sought to develop a pedagogical intervention in an electrical engineering class, preparing and executing a class to review content in the area of Mathematics. The content that was reviewed refers to basic trigonometry, as indicated by most students when asked about their greatest difficulties in basic Mathematics content. This research was developed at a Technical and Professional education school.

Regarding the space where this research was developed, the school has been part of the technical education market in the municipality of Canaã dos Carajás since 2020. Therefore, its mission is to offer technical professional qualifications in several courses, such as Administration Technician, Industrial Automation Technician, Nursing Technician, Electrical Engineering Technician, Electromechanical Technician, Building Technician, Logistics Technician, Metallurgy Technician, Computer Technician, Mechanical Technician, Mechatronics Technician, Environmental Technician, Mining Technician and Occupational Safety Technician.

The municipality of Canaã dos Carajás, in its social context, is home to people from different regions of the state and the country. The last demographic census, in 2022, carried out by the Brazilian Institute of Geography and Statistics - IBGE, showed that the municipality of Canaã dos Carajás was the one that grew the most nationwide.

Regarding this research, it is the result of a pedagogical intervention, as previously mentioned. Pedagogical interventions are actions or sets of actions that enable postgraduate students to act in response to a problem identified in a given school environment. They must be carried out by postgraduate students of the DocentEPT course, from the Institute of Education, Science and Technology of the State of Tocantins. The Pedagogical Project of the Course - PPC, provides in its statute that postgraduate students Teaching for Professional and Technological Education carry out a pedagogical intervention in a professional technical education institution.

Therefore, as a student of the DocentEPT course, I see that contact with teaching practice in the professional and technological environment is essential for a good academic education because, in addition to bringing new experiences with different themes for the training of postgraduate students, the course helps us to closely monitor the reality of professional education.

In this sense, this work has a research problem to identify which are the main theoretical contents of Mathematics that students have the most difficulty learning or understanding in the context of teaching electrical engineering.

Regarding the objectives of this work, it sought to develop an intervention proposal based on the results of the research, as previously mentioned, in which it will be verified which tools the students of the electrical engineering course use to learn Mathematics contents as well as identify their difficulties and apply a content review class.

METHODOLOGY

The methodology of this research is characterized as bibliographic research. According to Marconi and Lakatos (2018), bibliographic research is research that seeks to survey bibliographies already published, such as scientific articles (printed or digital), books, doctoral theses, and master's dissertations, for example. Regarding its importance, the authors emphasize that “its purpose is to put the researcher in direct contact with what has already been written” (Marconi, Lakatos, 2018, p. 33).

The research also stands out as field research, where a pedagogical intervention will be applied in a technical school. Contributing to this theme, Marconi and Lakatos (2018) point out that field research is where “the object is approached in its environment and the

collection of information is carried out in the natural conditions in which the phenomena occur" (Marconi, Lakatos, 2018, p. 32).

As for the form of analysis of research information, it was characterized as quantitative, where there was a survey in absolute numbers and percentages of the main contents that students had the most difficulty with in the area of Mathematics. Among the contents covered in this research, the contents of numerical expressions, algebraic expressions, percentages, trigonometry, and other subjects that could be mentioned by the students were addressed.

As for the data collection instrument, a questionnaire was applied to find out which main mathematics contents the students had the most difficulty with and which they would also like to review. After verifying the students' main difficulties, a class (pedagogical intervention) was given to work on a content review with the class.

In addition to seeking to answer these questions, the electrical engineering class sought to answer some other questions regarding the way they study the mathematics content. In this sense, the first question sought to answer how each student considers themselves in terms of learning themes or contents in the area of mathematics. As for the second question, it sought to know which methods the students in the electrical engineering class use to study or learn mathematics. In the third question, the students should indicate or describe whether they use any application to help their learning. Thus, this research was conducted with a total of 18 students from the electrical engineering technical course at a Technical and Professional Education school.

PROFESSIONAL AND TECHNOLOGICAL EDUCATION: REFLECTIONS

The purpose of technical and professional education, within the scope of its existence, is to promote access to quality education inherent in the training of professionals qualified for the job market. On this subject, Moura (2008) emphasizes in his research work that, for technical education to advance in the face of its challenges, teachers, institution managers, and technical-administrative staff need to be properly trained in the professional field. In this sense, the author points out the following:

Education and training must, therefore, go beyond the acquisition of teaching techniques for transmitting content for teachers and management techniques for managers. Evidently, these aspects will continue to be important, but the macro objective is more ambitious and should prioritize training within the scope of the country's public policies, especially educational ones, with a view to overcoming the current socioeconomic

development model, so that human beings should be prioritized more than simply market relations and strengthening the economy (Moura, 2008, p. 30).

In this text, Moura (2008) brings some reflections on teacher training in EPT, according to the author, the training of these professionals should go beyond technical and didactic skills, that is, it is necessary to train in accordance with the public policies in force in our country.

From this perspective, the author also highlights that Professional and Technological Education, as well as teacher training to perform this important function, requires that the "teacher must assume another attitude, forged from another type of training, which must be critical, reflective and guided by social responsibility" (Moura, 2008, p. 30).

Still in this perspective, regarding teacher training for EPT, Moura (2008) points out that the training of this professional follows two strands or axes, namely: the initial training of the professional and the second referring to the didactic-political-pedagogical training. The first, according to the author, as it refers to the initial training of the professional, should seek continued training in the area of activity itself. The second, the didactic-political-pedagogical, deals with specificities that are related to training for EPT.

Collaborating with the ideas of Moura (2008), especially what refers to treating the teaching of EPT in line with public policies, Pacheco (2020) points out in his article, unraveling the federal institutes: identity and objectives, some particularities of the social function that the IFs have to provider before society.

Thus, according to Pacheco (2020), federal institutes, or IFs, were created by federal law no. 11,892/2008, to offer free public education in a democratic context, enabling the most excluded classes of our society to access professional and technical education. One of the objectives of IFs is to work on professional technical education in conjunction with other modalities such as distance education-EAD, for example, and also extension projects that are focused on the socioeconomic conditions in the territory where the institution operates (Pacheco, 2020).

When discussing the institutionality of federal institutes, Pacheco (2010) points out that they must contribute beyond "national technological development", but as a factor that is decisive for the inclusion of millions of Brazilians.

Thus, the author makes the following statement:

> In this context, the Federal Institute points to a new type of institution, identified and aligned with the social project underway in the country. It therefore represents a qualitative leap in a unique journey, about to complete one hundred years. It is a progressive project that understands education as a commitment to transformation and enrichment of objective knowledge capable of modifying social life and giving it greater meaning and scope in the whole of human experience, a proposal

> incompatible with a conservative vision of society. It is, therefore, a strategy for political action and social transformation (Pacheco, 2010, p. 16).

In this way, the author describes that technical institutions or federal institutes have the role of valuing "education and public institutions, aspects of current policies assumed as fundamental for the construction of a sovereign and democratic nation, [...]" (Pacheco, 2010, p. 16).

Like the other authors cited above, Pacheco (2010) highlights the idea that federal institutes arise from the need to have public and social policies that provide access to education in a more equal and democratic way. In the political sphere, the author highlights that federal institutes "represent the overcoming of reductionist views and the establishment of a public policy that contributes to the realization of a viable national project for this century." (Pacheco, 2010, p. 16).

MATHEMATICS TEACHING IN EPT

Vocational and Technological Education is an area of education focused on training professionals who are duly qualified for the job market. It is understood that EPT students should also be motivated by the development of critical thinking about their learning. Thus, according to Pontes (2022), in his studies, he highlights that professional and technological education requires that teaching practice in Mathematics has the intention of reducing the gaps between Mathematics itself and current technological tools. In this sense, the author highlights: "The teaching of Mathematics in EPT needs to follow the best strategies to associate its concepts, rules, and relationships with the new technologies of Mathematics Education, aiming at the professional qualification of the learner" (Pontes, 2022, p. 3).

This is also described by Pinheiro (2020), on the use of technology in professional education, who says:

> Using technology in favor of teaching Mathematics offers different opportunities for students to observe, create, and discuss the results. Currently, several programs assist teachers in their classroom dynamics, making it possible to create situations in which students can interact with the subject creatively. However, the professional needs to know these tools so that he can advise students skillfully (Pinheiro, 2020, p. 5).

In this sense, it is important to highlight that the existence of technological tools does not mean that everyone knows how to use such instruments as learning facilitators. Regarding technologies, Pinheiro (2020) states that:

> Through the use of computers, the ability to solve problems has increased and the ways of approaching mathematical content that were previously seen only through calculations, without illustrations, are changing, thanks to the encouragement that

> professionals have been giving to students, as it is of utmost importance that they can broaden their knowledge about the different forms of resolution and thus put into practice new plans involving interaction and simulation of data (Pinheiro, 2020, p. 6).

Thus, according to Pinheiro (2020), the use of technology is fundamental to assist students in learning Mathematics in professional and technological education, and, for this to occur effectively, it is necessary to encourage students and teachers to develop teaching-learning.

Also on the subject of teaching mathematics in professional education, there are the considerations of Gonçalves and Pires (2014) who worked on interdisciplinarity as a way of integrating mathematics learning. In this way, the authors highlight the importance of the glimpse of interdisciplinarity that functions as a requirement that is given by society itself due to the fragmentations caused by science. Thus, the authors believe that:

> For an interdisciplinary approach to Mathematics to occur in High School and Professional Education, we believe the organization of pedagogical work in schools must happen in a collective, participatory, and democratic way. Thus, teachers can glimpse other teachers' perspectives of treating concepts beyond the boundaries of the disciplines that reflect on the disciplinary training of teachers (Gonçalves; Pires, 2014, p. 246).

These authors also emphasize that teaching mathematics, whether for high school or professional education, “can be materialized from a collective pedagogical practice in the school that permeates its organization in the macro dimension and at the curricular level” (Gonçalves; Pires, 2014, p. 246).

For the authors, speaking of disciplinarity refers to the integration of disciplines, that is, their combination to teach a science. Regarding the difficulties in learning mathematics in technical education, there was a study conducted by the authors in three subsequent courses at IFMG – Instituto Federal de Minas Gerais. In this study, the authors were able to verify the difficulties in learning applied mathematics content in the courses of Mechanics, Building, and Mining. Regarding the importance of mathematics in technical education: “It is known that Mathematics is an indispensable discipline for these students due to the great applicability of its concepts and techniques in other disciplines and the future career” (Viana et al., 2017, p. 393). Through these ideas, it is possible to identify that mathematics has great relevance in the technical area, because it functions as if it were a basis for the segment of many professions. Thus, for Viana et al., (2017), according to their studies, mathematics is like a work tool, where if students have difficulty, they will be in a position to hinder their professional practice. Still, on the subject of mathematical practice in technical education, Silva (2021) highlights in his research the contributions of mathematical modeling in an electrical engineering class. In this work, the author focuses on the content

of power factor, which is a topic focused on the study of electric motors. It is worth noting that this content contains many mathematical calculations and operations to discover the power and performance of motors. In this sense, Silva (2021) was able to prove, through mathematical models, the resolution of some calculations applied to the discipline of electric motors, such as the use of Pythagoras' theorem in solving the subject of power factor.

REPORT ON THE PEDAGOGICAL INTERVENTION

The activities for the pedagogical intervention began on November 13, 2023, with two moments of classroom observation. Thus, on November 13, there was the first contact with the electrical engineering class at the Vale do Pará Technical School – ETVP. In this first moment, notes were taken on the content that was taught in the subject of the electric motor and also how the learning dynamics were constructed between the subject teacher and the students.

Likewise, on November 14, observations and notes were continued. Among the notes on the content, the demonstration of the theoretical part of the operation of electric motors and their applications can be highlighted. Descriptions were made on the types of currents used in motors, such as single-phase alternating current systems and three-phase alternating current systems. Regarding the observed content, we can also mention the following topics that were covered: the relationship between power torque, efficiency, frequency, maximum current voltage, maximum current, series and parallel connections, delta connection, line current, stator and rotor, and slip of an electric motor.

Having made these considerations, regarding the calculations to determine the slip of an electric motor, some students had some difficulty concerning the sequence of procedures to perform the mathematical operations of the aforementioned subject.

Therefore, as a better way to measure the students' difficulties with the basic mathematics content, a questionnaire was applied on November 20th to the electrical engineering class. The questionnaire had 5 objective questions that aimed to identify at what level of learning the students considered themselves to be and which tools they used to study questions. Es mathematics, which applications they used to study mathematics, which content they had the most difficulty with, and which content they would like to see reviewed. Among the basic mathematics content, the following content was given to the electrical engineering class: Numerical expressions, Algebraic expressions, Percentage, and Trigonometry. If the students had any other content that they had more difficulty with, a blank option was left in which the students could describe it.

It is worth noting that the electrical engineering class at the Vale do Pará Technical School has around 40 students. However, the survey was conducted with only 18 students.

ANALYSIS OF RESULTS

The first question aimed to verify at what level of learning, in mathematics content, the students of the electrical engineering technical course considered themselves to be. Thus, the options were described as a) Excellent, b) Good, c) Regular, and d) Insufficient. Thus, the following table shows the results obtained.

Table 1 – Level of Learning in Mathematics Among Students

Level of Learning	Absolute Frequency	Relative Frequency (%)
Excellent	0	0
Good	8	44.44
Average	10	55.55
Insufficient	0	0
Total	18	100

Source: The Author (2023).

From the data shown in the table, it is possible to verify the perception that students have of themselves when it comes to Mathematics in their learning. Thus, in absolute numbers, there were 8 students who considered themselves good at Mathematics content, totaling 44.44% of the students interviewed. Regarding the students who considered themselves average when it comes to Mathematics content, 10 were found to have average knowledge in this subject.

These results describe the levels of knowledge of the class and show that no student considers themselves excellent in the area of Mathematics. Thus, there is a need to work more on Mathematics content and create actions such as extension projects or continuing education for technical and professional training.

The second question aimed to verify which tools the students in the electrical engineering class used in subjects that involved the use of calculations. In this sense, the options were scientific calculators, regular calculators, applications, software, or whether they usually performed calculations by hand. A blank option was also inserted so that students could mention another form or tool. Table 2 describes the results achieved in the interview.

Table 2 – Tools Used in Calculation Subjects

Tools	Absolute Frequency	Relative Frequency (%)
Scientific Calculator	2	11.11
Regular Calculator	11	61.11
Apps	1	5.55
Software	0	0

Manual Calculation	4	22.22
Total	18	100

Source: The Author (2023).

As described in Table 2, only two students reported using scientific calculators in calculation subjects, totaling 11.11% of the respondents. Meanwhile, 11 students use regular calculators or their smartphones, corresponding to 61.11% of the class. Regarding the use of apps, only one student declared using this type of tool, representing just 5.55% of the interviewed students. No students reported using the software. Concerning manual calculations, only four students stated that they practiced this learning method, making up 22.22% of the class.

These results reveal students' practices concerning Mathematics-related content. The majority rely solely on regular calculators to solve problems in class. In this sense, software or programs are not utilized as learning tools, highlighting a potential area for improvement in Mathematics teaching and learning in technical and vocational education.

Regarding the third question, which refers to the type of apps students use in electrotechnics classes, the following results were obtained, as described in Table 3.

Table 3 – Apps Used by the Electrotechnics Class

Apps	Absolute Frequency	Relative Frequency (%)
PhotoMath	0	0
Symbolab	0	0
Mathematics Calculator	8	44.44
Mathway	0	0
Other	1	5.55
Not Applicable	9	50
Total	18	100

Source: The Author (2023).

Based on the results shown in the table above, eight students use the Mathematics Calculator app, representing 44.44% of the class. In absolute numbers, nine out of the 18 students responded that they do not use any apps, totaling 50% of the class. Only one student stated they use a different type of app or technology, specifically mentioning ChatGPT.

The results indicate that the most commonly used apps are simple mathematical calculation tools, such as the Mathematics Calculator app. This suggests that students in the electrotechnical class rely on these tools solely for performing basic arithmetic operations.

Regarding the fourth question, which aimed to determine which Mathematics-related content students in the electrotechnics class struggle with the most, the results are shown in Table 4.

Table 4 – Mathematics Topics Students Struggle With

Difficulty	Absolute Frequency	Relative Frequency (%)
Numerical Expressions	0	0
Algebraic Expressions	7	38.88
Percentage	2	11.11
Trigonometry	9	50
Other	2	11.11
Total	20	111.1

Source: The Author (2023).

Regarding the greatest difficulties reported by the electrotechnics students in basic Mathematics, the results were as follows: no students reported difficulties with numerical expressions. For algebraic expressions, seven students stated they had difficulties, making up 38.88% of the respondents. Only two students reported struggling with percentages, representing 11.11% of the class. Regarding trigonometry, nine students declared they had difficulties with this subject, accounting for 50% of the class. Additionally, two students mentioned difficulties with other topics, such as logarithms.

The table shows that two students struggled with two different topics, which explains why the absolute frequency total appears as 20 instead of 18, and the relative frequency reaches 111.1% instead of 100%.

According to the data, many students struggle with algebraic manipulations and trigonometry-related content. This indicates that in subjects like electrical motors—which require knowledge of sine and cosine functions to calculate, for example, a motor's power factor—students may face difficulties if they do not grasp the fundamental concepts of trigonometry.

For the fifth and final question, which asked students which topics they would like to be reviewed, the results are shown in Table 5.

Table 5 – Topics Students Would Like to Review

Review Topic	Absolute Frequency	Relative Frequency (%)
Numerical Expressions	3	16.66
Algebraic Expressions	7	38.88
Percentage	2	11.11
Trigonometry	9	50
Other	2	11.11
Total	23	127.76

Source: The Author (2023).

The data in the 5th table show that 3 students requested a review of numerical expressions, representing 16.66% of the class. For the content of algebraic expressions, there were 7 identifications, that is, 38.88%; for the content of percentages, 2 students requested a review of the given content, totaling 11.11% of the class.

In the context of trigonometry, 9 students expressed themselves in favor of a review of this content, that is, 50% of the class. Once again, 2 students, or in relative numbers 11.11% of the class interviewed, identified the content of the logarithm in the blank space, this time for a content review. It is also possible to see in Table 5 that, of the 18 students who answered the questionnaire, 2 students requested 3 reviews (algebraic expressions, percentages, trigonometry), (numerical expressions, algebraic expressions, trigonometry) and 1 student requested two reviews (numerical expressions and algebraic expressions). Hence, there is an absolute and relative frequency difference between 18 and 100%, respectively.

Through these results, it is understood that there is a need to review these concepts since trigonometry serves as a basis for understanding the subject of electric motors. Furthermore, as perceived during classroom observations and the teaching of the subject teacher, the content of electric motors that were seen also addresses trigonometric functions, explaining how they work.

REVIEW OF TRIGONOMETRY CONTENT

According to the data obtained in the research, a class on the content of Trigonometry was demonstrated for the electrical engineering class. The aforementioned class took place on November 27, 2023, at the Vale do Pará Technical School, under the supervision of the professor of the electric motors discipline.

This theme contributed to the electrical engineering class some content and topics related to the electrical motors discipline, such as what the sine, cosine, and tangent of an angle are. Because, according to the discipline's demand, these topics were applied in mathematical formulas to solve some problems, such as finding the power or efficiency of an electric motor which, in this case, uses the cosine ratio of angles.

Thus, during the class, the sine, cosine, and tangent ratios in a right triangle were worked on. There was also a demonstration of some properties of trigonometry, such as trigonometric ratios; the relationship between sine, cosine, and tangent of acute angles; sine and cosine of complementary angles; the fundamental relationship of trigonometry; the relationship between sine, cosine, and tangent and sine, cosine and tangent of notable angles.

During the class, it was noticed that many students had difficulty with basic mathematics, such as the addition of fractions with the same denominators, rooting, and also with respect to division.

Therefore, the class was developed in an interactive way, seeking to discuss the difficulties of the students regarding the methods used to solve the questions. Therefore, in order to better follow the class, an activity was distributed to each student to be answered. In this activity, there were some applied questions of the right triangle and also demonstrations of trigonometry regarding the concepts of sine, cosine, and tangent.

FINAL CONSIDERATIONS

The work intended to show the results of research carried out with an electrical engineering class at a technical education institution subsequent to high school. The research was carried out at a technical and professional education school from November 13 to 27, 2023.

From the results obtained, it is possible to infer that most students had difficulties with mathematics content, such as algebraic expressions (38.88%) and trigonometry content (50% of the class had difficulty), respectively. Based on these results, a class was given to the aforementioned class on trigonometry content. In this class, students were able to recall some concepts such as sine, cosine, and tangent, which were used in the electrical engineering course subjects in an applied way.

It was also possible to provide a diagnosis of the profile of the electrical engineering class about the way they study and learn content in the area of Mathematics. Thus, most students considered themselves to have regular learning in Mathematics. Given this, it is possible to confirm the difficulties pointed out by some authors about the low Mathematical performance of high school graduates in basic learning.

Another point to be noted was the study tools used by students for mathematical calculations. Half of the class indicated that none of the tools such as applications and software were used to learn Basic Mathematics. Only part of the class described using the Math Calculator application, or they only use a calculator to perform calculations in the classroom. Discipline. Thus, it is possible to conclude that there is a need to develop new techniques or tools for learning electrical engineering content or even encourage the initiative of seminars for the development of applied themes that encompass Mathematics and the electrical engineering course.

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