Hermeneutics and the work of the mathematics teacher: a possibility of work in differential and integral calculus classes

La hermenéutica y el trabajo del docente de matemática: una posibilidad de trabajo en las clases de cálculo diferencial e integral

L'herméneutique et le travail du professeur de mathématiques: une possibilité de travail en cours de calcul différentiel et intégral

A hermenêutica e o fazer do professor de matemática: uma possibilidade de trabalho nas aulas de cálculo diferencial e integral

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Abstract

This article aims to present a method of intervention in the classroom, specifically in the Differential and Integral Calculus course of a Mathematics Teaching degree, when working with students on the Intermediate Value Theorem. We base our approach on the studies by Bicudo (1991), Garnica (1992), and Garnica and Bicudo (1994) regarding a teaching methodology based on hermeneutic work with mathematical texts in the classroom. We describe the experience conducted and our understanding of the activity carried out. We present the questions posed by the students and the indications of their understanding of the ideas introduced in the studied theorem.

Key-words: Mathematical Education, Calculus, Intermediate value theorem, Didactic hermeneutics

Resumen

Este artículo tiene como objetivo presentar un modo de intervención en el aula, en la asignatura de Cálculo Diferencial e Integral, de un curso de Licenciatura en Matemáticas, cuando trabajamos con los estudiantes de esta asignatura el Teorema del Valor Intermedio. Tomamos

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como base los estudios de Bicudo (1991), Garnica (1992) y Garnica y Bicudo (1994) sobre una didáctica basada en el trabajo hermenéutico con textos de matemáticas en el aula. Relatamos la experiencia realizada y nuestra comprensión sobre la actividad llevada a cabo. Presentamos las preguntas planteadas por los estudiantes y los indicios de sus comprensiones sobre las ideas introducidas en el teorema estudiado.

Palabras clave: Educación Matemática, Cálculo, Teorema del valor intermedio, Hermenéutica didáctica.

Résumé

Cet article a pour objectif de présenter un mode d'intervention en classe, dans la matière de Calcul Différentiel et Intégral, d'un cursus de Licence en Mathématiques, lorsqu'on travaille avec les étudiants de cette matière sur le Théorème de la Valeur Intermédiaire. Nous nous appuyons sur les études de Bicudo (1991), Garnica (1992) et Garnica et Bicudo (1994) concernant une didactique basée sur le travail herméneutique avec des textes mathématiques en classe. Nous décrivons l'expérience réalisée et notre compréhension de l'activité menée. Nous avons inclus les questions posées par les étudiants et les indices de leur compréhension des idées introduites dans le théorème étudié.

Mots-clés: Éducation Mathématique, Calcul, Théorème de la valeur intermédiaire, Herméneutique didactique.

Resumo

Este artigo tem como objetivo apresentar um modo de intervenção em sala de aula, na disciplina de Cálculo Diferencial e Integral, de um curso de Licenciatura em Matemática, quando trabalhamos com alunos dessa disciplina o Teorema do Valor Intermediário. Tomamos como base os estudos de Bicudo (1991), Garnica (1992), Garnica e Bicudo (1994) a respeito de uma didática baseada no trabalho hermenêutico com textos de matemática em sala de aula. Relatamos a experiência realizada e nossa compreensão sobre a atividade desenvolvida. Trouxemos as perguntas postas pelos alunos e os indícios de suas compreensões sobre as ideias trazidas no teorema estudado.

Palavras-chave: Educação Matemática, Cálculo, Teorema do valor intermediário, Hermenêutica didática.

Hermeneutics and the work of the mathematics teacher: a possibility of work in differential and integral calculus classes.

We use the studies of Bicudo (1991), Garnica (1992), Garnica and Bicudo (1994), in which they present a didactic based on the hermeneutic way of working with mathematics texts in the classroom, as a basis for the subject of Differential and Integral Calculus in a Mathematics undergraduate course. Our objective is to present a way of working from the perspective of the hermeneutic practice of the teacher with the students in the classroom when we work on the *Intermediate Value Theorem.*

Several studies – mainly in the field of Mathematics Education – present data that reveal the challenges faced in higher education courses in exact sciences that involve the subject of Differential and Integral Calculus. Studies such as those by Wrobel, Zeferino and Carneiro (2013) discuss the learning difficulties faced by students in most Brazilian universities which causes high failure and dropout rates in the first semesters of courses in the exact sciences area. Pagani and Avellato (2014) carried out a mapping of theses and dissertations that address the teaching of Calculus and identified that the main motivation for work on this topic is the high failure rates in the subject. There are studies that specifically address the problems with Calculus concepts in Mathematics Undergraduate courses, such as those by Silva, Nascimento and Vieira (2017) and Santos and Matos (2012). In these works, the authors highlight the existence of epistemological, didactic, emotional and material obstacles that interfere in the teaching and learning process, as well as in the teacher's didactic methodology. They also highlight the lack of prior learning of concepts and knowledge on how to operate them, on the part of the students, characterized as a "lack of prerequisites". Agreeing with Rezende, we understand that a work that aims at the possibility of producing mathematical knowledge should be accompanied by a focus on Calculus itself. This author states that "teaching Calculus must be directed towards Calculus itself, its meanings, its constructive problems and its potentialities" (Rezende, 2003, p. 432), because "knowing their meanings is just as important as knowing how to use the rules of derivation and the techniques of integration" (Rezende, 2003, p. 432).

This article is organized into five sections, being the current one an initial introduction to the topic. The second section presents the theoretical aspects of the proposal, focusing on important themes for understanding the work, such as language, discourse and text; hermeneutics; and the mathematics text. The third section presents the research methodology chosen for this work. The fourth section reports on what happened in a work developed with hermeneutic action in the classroom, when we were with students of the Differential and

Integral Calculus discipline, highlighting the ways in which a text about the "Mean Value Theorem" can be understood. The fifth section articulates ideas, highlighting those of concepts, form, rigor, statements, definitions, and theorems, presenting a comprehensive analysis of the work carried out in view of the proposal of this article.

Theoretical aspects of the proposal

In this section, we present the work of Bicudo and Garnica, highlighting the theoretical aspects that are relevant to understanding the didactic proposal that will be presented. These are Language, discourse and text; hermeneutics; and the mathematics text.

Garnica (1992) begins his work by proposing a reflection[3] on the following questions: Can a Mathematics text be read hermeneutically? Can the work of a Mathematics teacher be seen as the work of a hermeneutist? In this way, we intend to clarify here – even if briefly – fundamental components for the work of reading the proposal. It is important to highlight that in this work such terms are understood – in the light of the works of Heidegger (1989) and Ricoeur (1987).

In relation to language, discourse and text, for Ricoeur, hermeneutics must prioritize three elements to establish a hermeneutic project: discourse, text and the apparently conflicting positions assumed in interpretation (Garnica, 1992). With Ricoeur (1987), we understand language as discourse, speech or text; and discourse, as an articulation of intelligibility, appears as a form of manifestation of language: of a language 'event'.

Garnica (1992) highlights that events are transitory and fade away, but their meanings do not. Hence, this event/significance dialectic is shown fruitfully in communication. It is a way for human beings to be in their worldliness; however, the human being, as a being in communication, always expresses his understanding, based on lived experience. According to Ricoeur (1987), the lived experience, as an experience, remains private, but the sense of its significance becomes public.

The text is also understood – according to Ricoeur's conception – as a discourse fixed by writing, where the written word is captured by orality through graphics, which represent the articulations given by this orality. In the written text, there is a distance from the spoken word, since it comes after the word. Thus, the question of meaning reappears in the possibility of

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[3] We understand 'thinking' as an articulating movement carried out in the subjectivity of a subject, with ideas explained by other people or authors, conveyed in texts that carry with them historical-cultural contexts, together with situations that trigger questions, doubts, astonishment, and uneasiness. Therefore, thinking does not occur in a vacuum, in a situation in which the thinking being is isolated and creates "truths"; he/she is always nourished by the materiality made possible by being-with the world and living beings.

being revived in the reading of such material landmarks. Hence, much more than a simple mechanical decoding of signs, reading should be seen as a possibility of revealing the world to the reader through what is said in language. The discourse (Ricoeur, 1987) is linked to a material support, such as signs, drawings, gestures, sounds, words, grammar, sculptures, and is articulated by a message intended by the author. The expression conveyed by language and articulated as text is freed from the author who says it, requiring from the one who reads it, in the sense that he interprets it, an analysis to revive what was said, its message, and the context in which it was uttered. When the text is written in a language structured by logic, it can remain inactive, as if it were dead, as it is not brought to life among people who take it up again, interpreting it and bringing more sense and meaning to what is said. We consider reading as a dialogue between the reader and the author's intention to say, which enables the understanding of the discourse and the intention to say in the context in which it was said. The excerpt below clarifies this statement:

> In understanding what is said by the text, several factors interact, creating the dynamics of interpretation. The following factors act in this understanding: the rights of the author who, in the text, places his perceptions and experiences in the desire to make them public, in the eagerness to communicate; the rights of the text that he carries along, regardless of how and when it was generated, the material marks that convey the message; the rights of the reader who can appropriate the meaning of the text, transform it and reinterpret it freely, retell it, recontextualize it (Garnica, 1992, p. 09).

Ricoeur (1987) emphasizes that the rights of the author and the reader converge in a struggle that constitutes the dynamics of interpretation, so that the interpretation/understanding of the text begins where the struggle ends, given in the dialogue of these actors. When the reader opens himself to what is said in the search, he/she assumes a posture of understanding and interpreting the text and the context of its event.

In relation to hermeneutics. Bicudo (1991) and Garnica (1992), referring to the authors studied, highlight some of the meanings given to this word: designating a (1) theory of exegesis (theory of analysis, explanation of a work) or a (2) theory of understanding. The following significant orientations given to the word hermeneutics are also highlighted: to say, to explain and to translate. These guidelines, as we understand in Bicudo's text (1991), can be brought to school education when we characterize teaching as a hermeneutic task, since the teacher's activity is shown to be that of a hermeneutist when interpreting and translating the text that refers to the subject he teaches. As stated by this author, in the search to make the text clear, that is, to take it out of obscurity, for his students, the teacher

[....] expresses out loud, says through words and actions, what he himself understands about what he has understood. To this end, he classifies and makes his speech rational. He translates what is to be said, in an attempt to make what is foreign, unintelligible to the student, become familiar to him. In this aspect, he operates as a mediator between the world laid bare by the subject he teaches, his horizon of understanding and that of the student (Bicudo, 1991, p. 92).

We understand that, in the work of the mathematics teacher, hermeneutics opens up possibilities for understanding what is said, indicating ways of entering into what is said in the text and providing clarification of its content.

Teachers and students have different horizons of understanding, as they are situated-in-the-world[4], perceiving others and other beings and perceiving themselves with them. The fact that they belong to a time and space gives rise to the teacher and student having a common ground in which they exist and live their experiences, enabling understanding of what is said in the text. Belonging to the world-of-life can enable openness to the text and understanding through interpretation; however, the attribution of meaning is an elaboration of the interpreter. In the fusion of the horizons of understanding between teacher and student, the text reveals its message, so that it can be incorporated into both horizons, each in its own way (Garnica, 1992).

We therefore have that in the meaning we do not notice patterns, as it occurs in the subjectivity of each person in their being with the other.

On the Mathematics text. The mathematics text presents the discourse of Mathematics, conveying contents of this science (Garnica, 1992). This "presentation", according to the author, is related to presentational thinking which, according to Heidegger's critique (1989), is a term that refers to propositions and concepts already formulated, derived from a previous understanding and interpretation. Garnica also highlights Ricoeur's critique (1978) that suggests the immediatistic form of understanding, given by a mechanistic reading of a text, as something woven by presentational thinking and that fails in terms of understanding, as it requires reflection. Furthermore, according to this author,

Mathematics texts are given in this presentational way, without any connection to historical and contextual elements, which contributes to the lack of understanding of these texts. This is reinforced if the interpretation of these texts is done in a technical way, where what is said in the text is not understood/interpreted, but simply associated with a meaning that has been maintained over time and finds, especially in the classroom, an appropriate means to maintain itself (Garnica, 1992, p. 25).

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[4] World, the place where we are and exist, understood as the world-of-life, Lebenswelt, which brings with it the historicity of the present, past and future in a synthesis of the now lived by each one of us at the moment in which the experience takes place, and by all of us, in the intersubjective dimension that is historical-sociocultural.

With this, the author highlights that Mathematics texts may not be appropriate, from a pedagogical point of view, sometimes due to excessive symbolism, or because they are treated, first and foremost, at a presentational level.

We ask, Garnica (1992), how can we overcome this presentational aspect of the Mathematics text? This is where the importance of a hermeneutic work that integrates, in its reading, the anxieties, needs, searches and difficulties of the student as a reader, situated in the context of the classroom, reveals the way in which they perceive Mathematics and perceive themselves as Mathematics students, being in the world with others and with Mathematics.

For a hermeneutic phenomenological proposal

When developing a work of text interpretation, considering the elements presented in the previous section and with the main objective of *understanding the context, understanding that the interpreter, as an interpreter, is immersed in a context in what we call 'hermeneutic approach'*, we highlight and take as guidance an activity carried out with students of the Mathematics Degree course, as pointed out by Bicudo (1991), Garnica (1992), Garnica and Bicudo (1994) regarding a hermeneutic work in Mathematics texts, that is:

a) the hermeneutic approach to Mathematics texts is possible;

b) the hermeneutic approach, understood as an action of retaking what is understood to one that is to be understood, carries the possibility of the reader understanding the meanings of Mathematics terms more clearly with each retake;

c) the hermeneutic approach to Mathematics texts allows the reader/interpreter to exercise criticism of the context.

For the didactic-hermeneutic experience, we take a text from the book *Calculus – Volume I*, by James Stewart, about the *Intermediate Value Theorem*, analyzing it and discussing aspects considered important in this discipline. This theorem stands out in the discipline of Differential and Integral Calculus because it describes an important property of continuous functions: for any function *f* that is continuous in the interval [*a,b*], the function will assume any value between *f(a)* and *f(b)* in the interval.

The work carried out – described in this article – was based on the hermeneutic approach, albeit in a classroom context, in the subject of Differential and Integral Calculus, and in a Mathematics undergraduate course. Thus, the works mentioned in the previous item were studied, understood and interpreted, considering the reality of the classroom in which the experience reported here occurs in a hermeneutic movement, keeping the focus on the understanding of the mathematical text.

The mathematics text used as the object of work with students for reading and understanding the Intermediate Value Theorem was presented as follows:

"Intermediate Value Theorem: suppose that the function *f* is continuous in a closed interval [*a,b*] and let *N* be any number between *f(a)* and *f(b)*, where *f(a)≠f(b)*. Then, there is a number c, in the open interval]*a, b*[so that *f(c) = N*''.

Initially, the teacher read the text with the students; then, each student was asked to read the theorem, highlighting (by underlining) all the terms that they considered important for understanding the theorem. Once this was highlighted, the students were asked to make a list of the selected terms, researching the meaning, or definition, of each of these terms.

As an example, we selected one of the highlighted texts in figure 1.

The terms highlighted were:

- Continuous *function* f;

- Closed *interval* [a, b];

- Let N be any number;

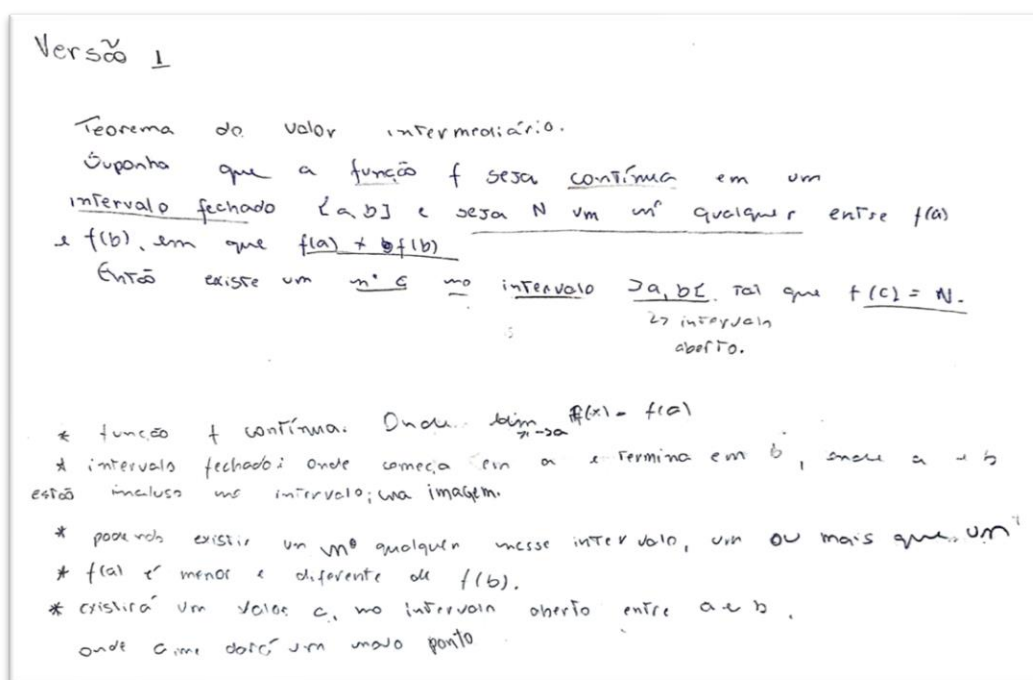- Interval] a, b[;

- f(c) = N.

Figure 1.

First part of the 2024 interpretative work (prepared by the authors)

The students were instructed to research the highlighted terms, both in the material from previous classes and on web pages that covered the subject; as well as in textbooks that were available in the classroom, and to record their understanding of each of these terms. Then, they

should reread the theorem, now with an understanding of all the highlighted words, and rewrite it according to this understanding. They could also use graphs that represented the statement, as shown in the image presented in Figure 2.
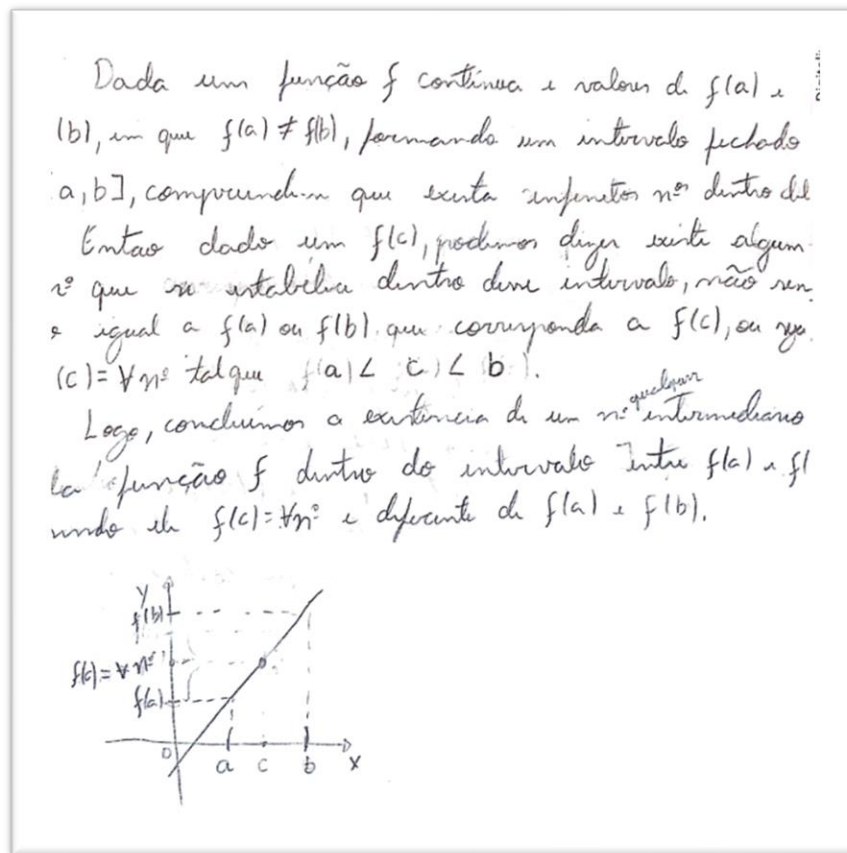

Figure 2.

Second part of the 2024 interpretative work (prepared by the authors)

During the activity, a third stage of the work began. With the theorem written on the board, students were encouraged to talk about their understanding of the interpretative work carried out, as well as any questions that this movement might have generated in relation to the proposed theme. We sought to create an atmosphere in which they felt free to present doubts and elaborate on some questions about the theme. And so, they proceeded, presenting the following questions:

(1) In the statement of the theorem, do *f(a)* and *f(b)* have to be an interval?

(2) Is *f(a)* always greater than *f(b)*?

(3) Is there more than one value of *c* or is this *c* unique?

(4) What would it be like if *f(*a*)* were less than *f(b)*?

The answers to these questions were often answered by other students, with the teacher remaining in the position of interlocutor. Our intention is to enter into the dialogic movement when requested or when we realize that clarification is necessary. By assuming this position, we expose some of our interferences: In question (1), we asked the class to carefully reread the statement of the theorem, to analyze what it says about $f(a)$ and $f(b)$ and to seek to direct their thinking towards conclusions. In question (2), we suggested that the students observe the position of $f(a)$ and $f(b)$ on the graph. Attentive to the movement of thinking that was taking place in the discussion, another student asked question (4), "What would it be like if $f(a)$ were smaller than $f(b)$"? Maintaining the position of guiding the movement of thinking, we did not give the answer, but we did pose a question, in a tone of doubt, with a view to keeping the search moving. We suggested, "can you draw this situation graphically?" We make the same suggestion for question (3), "is the value of c unique?". We emphasize the request to return to the statement of the theorem, analyzing what it says about c and ask, "what can we observe in the graphs produced?"

Paying attention to what happened in the classroom, together with the students, working on the text and the theme already mentioned, we realized that the questions formulated by the students differed from those that – in general – were posed in the classes in which we taught this theme. We understand that the work of the teacher who assumes a hermeneutic stance, working on the interpretation of the mathematical text, opens up possibilities for thinking among the students and with the teacher, with a view to understanding what is said in the text, which opens up beyond the text, and can, in this movement, also open up to understanding oneself, focusing on one's own way of proceeding. The movement of understanding (the text) is carried out by understanding oneself (becoming aware of one's own questions and understandings).

The text taken and studied in its context is shown to be open, generating questions, and is never taken as a stated truth. The opening that took place in the classroom for students to elaborate and talk about their queries and expose their questions took place in a dialogue between and with students and the teacher, in the sense of being an opening to the other, characterized as posing questions and searching for intelligible answers, within the scope of what was being discussed and that expanded to other situations.

Aware of the openness of thinking that was taking place in the classroom, we proposed the following questions: How could we graphically represent the idea of this theorem by setting N = 0? Where would N be on the Cartesian plane? In this case, what would the number c represent? We invited the students to think about these questions, suggesting possibilities for

graphically representing the situation. Images such as the one represented in figure 3 emerged, which shows the location of the value of N = 0, with indication of doubts about what, in this case, the number c would represent.
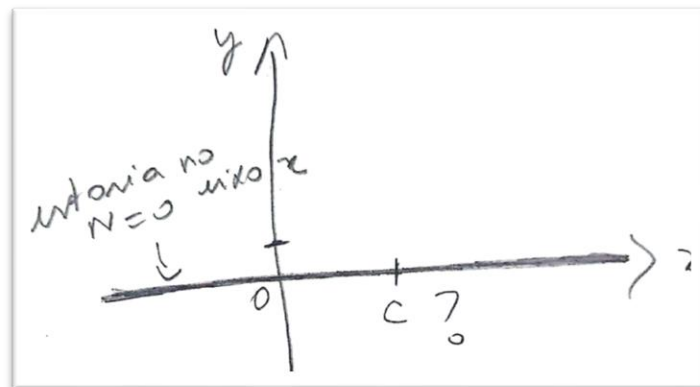

Figure 3.

Third part of the 2024 interpretative work (prepared by the authors)

We understand the question posed in Figure 3 as a silence that shows concern in the face of the new challenge. In order to indicate possible paths to understanding, we ask: how could the situation of N=0 be understood, so that one could understand what happens to the number c in this situation. In order to provide clues, we present the following example*: Show that there is a root of the equation* $4x^3 - 6x^2 + 3x - 2 = 0$ *between values 1 and 2.*

Figure 4 shows us what one of the students thought when analyzing the proposed example.

When students express this understanding, we move towards generating further understandings, working with Mathematics itself to clarify the ideas present in the proposed *theorem*. We launch challenges so that students think about what was thought and about the question to be thought about, avoiding mechanistic ways of presenting information. With this, we use a device of applying a mathematical element, contextualized within the scope of Mathematics itself, which can help in the desired clarity. In the experience presented here, we can highlight the elaboration of the graph referring to the proposed theorem as one of these devices. After interpreting the text hermeneutically, the students sketched a graph, in order to think about what was thought and about the question thought about, the meaning of the statement of the theorem.
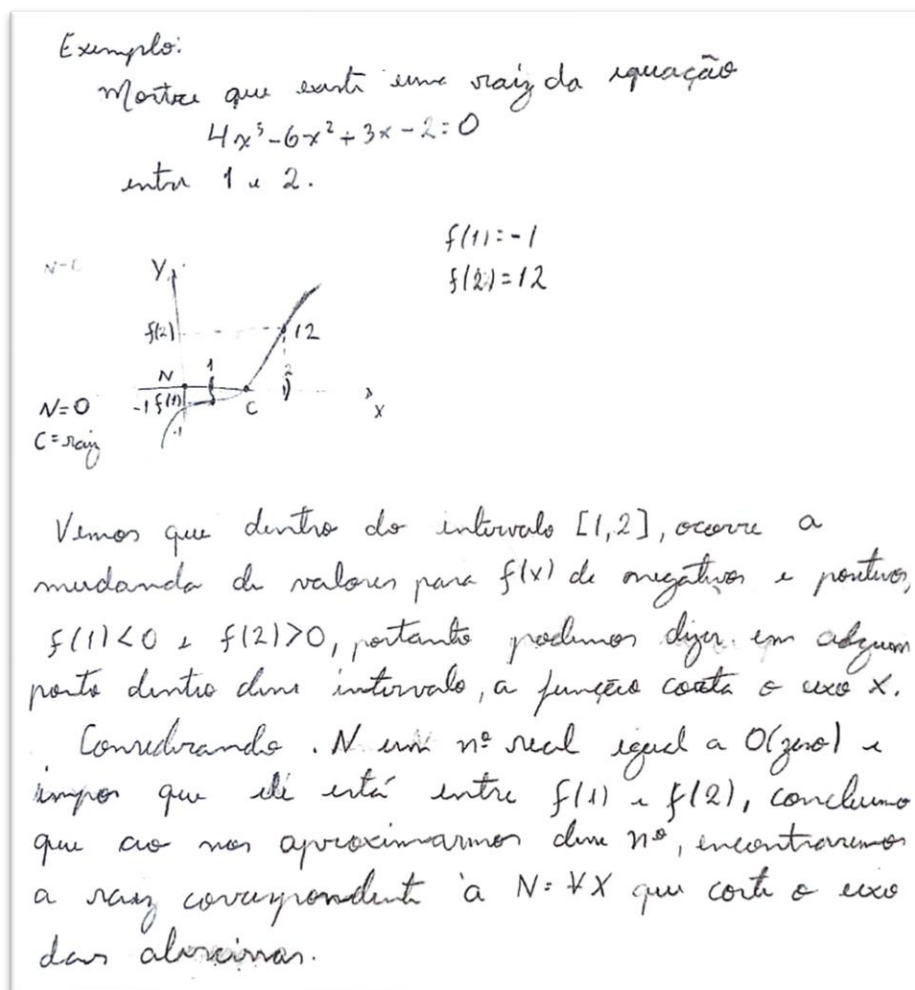
Figure 4.

Fourth part of the 2024 interpretative work (prepared by the authors)

The discussion carried out in the example illustrated in Figure 4 shows us the hermeneutic movement in the study of the text, allowing for back and forth, because to talk about this example, the student returns to the definition of the *theorem* presented initially, using the idea of the closed interval, bringing it to the example ("we see that within the interval [1,2] ...", when he writes *f(1)=-1 and f(2)=12*).

The mathematical text carries an intention to say, raising a question, whether explicit or not. The answers related to the questions proposed by the text and the posing of the question establish the reader's desire to think with the author, by focusing on the author's intention to say. The text presented in this activity proposed and carried out in the classroom shows that hermeneutic work opens horizons for the encounter between students, students and teacher,

with and together with the text and its respective context. This work links one way of thinking with another and with the text, starting with a careful reading by the reader (teacher-students), opening space for doubts and questions to be raised, discussed, and revisited, allowing other questions to be raised, prompting investigation, analysis, and discussion about the text, opening up horizons for understanding and interpretation in a movement that is evident as continuous.

When thinking about the activity carried out and the questions posed by the students, we understand that working by assuming the "doing of the mathematics teacher as a hermeneutic doing" is revealed as being powerful from the point of view of a hermeneutic/phenomenological didactic.

In conclusion: some understandings of the hermeneutic work of the mathematics text

The main proposal of this call, assuming that the teaching of Calculus is the focus of research in the field of Mathematics Education, is to bring together different theoretical structures, promoting different discussions on how Calculus could be taught. Attentive to this proposal, in this article, we present an intervention in the classroom in the discipline of Differential and Integral Calculus, focusing on the interpretation of the Intermediate Value Theorem, in the Mathematics Degree program at Unesp – Guaratinguetá, based on hermeneutic procedures grafted onto didactic actions.

To this end, the main theoretical contributions that support the proposal were brought up and, after that, the example of a work developed in the classroom.

We understand that, in order to conduct work on understanding and interpreting a mathematics text, the teacher must organize actions in advance, such as proposals for conducting a class, with the aim of discussing the text to be studied with the students, translating it, explaining it, stating the mathematical ideas conveyed by the text, helping the student to question the text, evoking their primary experiences, and criticizing the text. This is a task of making the mathematics that is taught intelligible (Bicudo, 1991), as well as opening horizons for mathematical practice.

With regard to teaching Calculus, this movement proves to be important and challenging, given the nature of the knowledge in this area of Mathematics that deals with

concepts rarely seen in Basic Education. Thus, making mathematical sentences full of meaning, promoting the understanding and interpretation of what is said in the text and the self-understanding of those who understand and interpret it make the work of the mathematics teacher a hermeneutic work (Bicudo, 1991). Revisiting the ideas outlined in this text, in the living present of thinking with the text and with the students, they come to life, illuminating a possibility for work.

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