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Reasons for learning and overcoming empirical thinking in the analysis of a measurement process[1]

Motivos da aprendizagem e superação do pensamento empírico na análise de um processo de medida

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ABSTRACT
This study investigates the motives attributed by students during a teaching and learning process centered on the appropriation of the concept of measurement. The research is justified by the fact that Brazilian educational and market-oriented policies encourage practices associated with empirical thinking. It is grounded in historical-dialectical materialism and in the theoretical frameworks of Russian psychologists and scientists. Twenty-two students from a technological undergraduate course at a public college in the state of São Paulo participated in the study. The methodological procedure involved a formative experiment designed in three stages: utilitarian, contradictory, and awareness-raising. Evidence was found of students' actions of deduction and analysis, motivated respectively by empirical thinking and the process of becoming aware of the internal properties of the instrument related to aspects of arithmetic and geometry. It is

RESUMO
O estudo investiga os motivos atribuídos por estudantes durante um processo de ensino e aprendizagem baseado na apropriação do conceito de medida. Justifica-se pelo fato de as políticas educacionais e mercadológicas brasileiras incentivarem práticas associadas ao pensamento empírico. Fundamenta-se no materialismo histórico-dialético e nas concepções das teorias de psicólogos e cientistas russos. Participaram da pesquisa vinte e dois estudantes de um curso superior de tecnologia de uma faculdade pública paulista. Como procedimento metodológico utilizou-se o experimento formativo planejado em três etapas: utilitária, contraditória e de conscientização. Constatou-se evidências sobre ações de dedução e análise de estudantes motivadas, respectivamente, pelo pensamento empírico e a tomada de consciência ao se reconhecer as propriedades internas do instrumento relacionadas aos aspectos da aritmética e geometria. Conclui-se que a superação do pensamento estritamente empírico na

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concluded that overcoming strictly empirical thinking in technological education depends on placing the student in contradiction through the organization of the teaching activity and the mediation of the teacher.

Keywords: Concept of Measurement. Mathematics. Learning motives. Empirical thinking.

educação tecnológica depende de colocar o estudante em contradição por meio da organização da atividade de ensino e da mediação do professor.

Palavras-chave: Conceito de Medir. Matemática. Motivos da aprendizagem. Pensamento empírico.

1 Introdução

Studies such as those by Antunes (1999), Arruda (2016), Machado and Machado (2018), Ferraz and Fernandes (2019), Silva (2019a, 2019b), Pereira (2022), and Silva (2023) characterize the hegemonic model of Professional and Technological Education (*Educação Profissional e Tecnológica* – EPT) in Brazil, which is supported by national education policies and institutional teaching guidelines. These frameworks exert considerable influence on how teachers and students assign meaning and attribute motives when analyzing the dynamics of teaching and learning processes in vocational education, particularly in relation to labor. In the context of EPT, the organization of teaching activity becomes more complex and challenging due to the technological means of production and the National Education Guidelines and Framework Law (*Lei de Diretrizes e Bases da Educação Nacional* – LDB) (Brasil, 1996), which tend to reinforce the reproduction of limited operational labor practices. Although such practices may be effective for technical services, they constrain the development of theoretical and critical thinking in both workers and students (Arruda & Moretti, 2019). Additionally, the LDB legitimizes the practice of teaching through *notório saber* (notable knowledge), allowing for the presence of the engineer-professor (Silva, 2019b; Hermoza, 2021), that is, professionals without formal pedagogical training — an element essential to the proper organization of classroom instruction.

These conditions contribute to the reinforcement of empirical thinking and the lack of student engagement with the appropriation of scientific knowledge. Professional experience, "learning to learn," know-how, competencies, and active

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methodologies used as ends in themselves prove limited when it comes to fostering human consciousness and comprehensive education in the fields of science, mathematics, and engineering (Duarte, 2001a, 2001b, 2004; Arruda & Zanotello, 2020; Ramos & Magalhães, 2022).

Notably, vocational schools have a particularly specific need to reproduce labor market practices and prepare students to perform specific operational functions in their related field. However, to raise students' awareness of the limits of habitual operations linked to the alienation of labor and to overcome the condition of empirical thinking, the research presented in this article is based on historical-dialectical materialism (Marx, 2013), the principle of the law of contradiction (Triviños, 1987; Marx, 2013), as well as the foundations of the historical-cultural perspective (Vygotsky, 2007), the theory of human activity (Leontiev, 2004), and the development of theoretical thinking (Davydov, 1988).

The study was conducted with twenty-two students enrolled in a technological undergraduate program at a public college in the state of São Paulo. The teaching process was structured based on the Teaching Guiding Activity (*Atividade Orientadora de Ensino* – AOE) (Moura, 2010, 2017, 2022) and the development of a formative experiment (Davydov, 1988; Vygotsky, 2004; Cedro, 2008). The objective was to investigate which motives are attributed by students during a teaching and learning process, and how consciousness is developed through the appropriation of a measurement process and its underlying mathematical aspects. For this purpose, a Triggering Learning Situation (*Situação Desencadeadora de Aprendizagem* – SDA) was designed, comprising stages related to operational use, contradiction,[4] historicity, and the creation of a measuring instrument.

To elucidate the learning motives attributed by students, based on the organization of teaching activity, this article presents: the theoretical conceptions that support the socio-historical importance of the instrument in the development

[4] This refers to the moment when students are presented with the limitations of the measuring instrument in obtaining the desired value.

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of human consciousness; the methodological foundations and the structure of the formative experiment; the analysis and discussion of results, drawn from an excerpt of a doctoral study that involves alienation, contradictions, and the appropriation of the measurement process; and final considerations regarding the achievement of the study's objective, with the aim of contributing to the integral education of workers and the development of consciousness within a challenging and contradictory context.

2 The Work Instrument and the Development of Consciousness

The structure of human activity involves "[...] psychologically characterized processes determined by what the process as a whole is directed toward (its object), which always coincides with the goal that stimulates the subject to carry out the activity, that is, the motive" (Leontiev, 2014, p. 68, our translation). Professional activity has an object, and mastery over it is required. The production of this object arises from preparation and conceptualization, as well as the use of materials and instruments, often adapted to fulfill the objective, that is, the activity oriented toward a specific goal (Marx, 2013; Moura, 2022).

Measurement is a practical necessity across various fields of science, mathematics, and engineering. A key element in carrying out this operation is the measuring instrument, which necessarily incorporates human objectifications shaped by the socio-historical characteristics of the individual, reflecting the needs involved in its creation and/or use in labor activities. In this sense, "labor has been, from its origins, mediated simultaneously by the instrument (in the broad sense) and by society" (Leontiev, 2004, p. 80, our translation).

In mathematics, ancient Egyptian civilizations needed to demarcate land after the Nile River flooded. Surveyors used ropes as instruments and, by tying knots along their length, created subdivisions to measure plots of land (Boyer, 2012; Rocho *et al.*, 2018). Thus, the process of measuring an object's length involves the fusion of two mathematical aspects: the geometric

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aspect, referring to the unit of measurement (in this case, length); and the arithmetic aspect, due to the need to repeat the operation and calculate the number of unit divisions (Caraça, 1951; Aleksandrov, Kolmogorov & Laurentiev, 1988).

In psychology, the creation and use of instruments in different contexts represent distinct forms of mediation and interaction within human activity, when considering contributions to the development of one's consciousness. For Vygotsky (2014), school learning guided solely by habit (use) may not transform students' psycho-intellectual characteristics. Thus, the mere use of an instrument becomes an action that turns into an operation, that is, an automatized habit that benefits little in the development of consciousness (Leontiev, 2004; Vygotsky, 2007). This reinforces the condition of empirical thinking, defined as follows:

> Empirical thinking allows the subject to carry out cognitive activity that enables the separation and naming of the attributes of objects or phenomena, including those that at a given moment are not directly observable and can only be understood indirectly through deduction (Rosa, Moraes & Cedro, 2010, p. 73, our translation)

The creation of instruments, on the other hand, may involve various forms of mental abstraction, distinguishing humans from other animals, since:

> For humans, the instrument is not merely an object with a particular external shape and defined mechanical properties; it appears as an object in which modes of action are embedded, work operations that have been socially elaborated (Leontiev, 2004, p. 180, our translation)

Thus, the integrated use and creation of instruments are fundamental to the development of human consciousness. According to Leontiev (2004), internal activity, which is theoretical in nature, and external activity, which is practical, have distinct characteristics but are not independent, as they share a common structure. "Therefore, external activity always includes external actions and operations, while internal activity includes internal

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actions and operations of thought" (Leontiev, 2004, pp. 126–127, our translation). Both practical external activity and theoretical internal activity are complementary and essential for the development of the human psyche and the formation of consciousness, especially when considering the production and use of an instrument and collective activity.

Conversely, the transformation of consciousness in a class-based society occurs through the process of alienation, the social division of labor, and the development of the productive forces, when the individual is separated from their material conditions, when the vast majority of producers have been turned into wage laborers, and when the connection between the worker and the land, the tools of labor, and labor itself has been severed (Leontiev, 2004).

Sociology points out that the productive restructuring of capitalism establishes significant changes in society and imposes goals, competencies, and pragmatism as the ideal framework for the productive world. In this context, trends of labor exploitation and precarization are intensified, often disguised as entrepreneurship, atypical work, cooperativism, and flexibility, among other means of promoting subordination and alienation from the meaning of labor (Antunes, 1999).

Above all, one of the teacher's responsibilities in the classroom is to awaken the motive of activity in the student. "A motive of activity is what, being reflected in a person's mind, impels them to act and directs the action toward satisfying a specific need" (Leontiev, 1961, p. 346, our translation). The existence of a need does not necessarily imply that the stimulus (motive) is sufficient to trigger activity; hence, there are motives that are effective and perceived. The relationship between the effective motive and the individual's need and action is exemplified below in a simple way.

> One day, in very bad weather, a hiker who is feeling very cold has the need to warm up. He feels cold and wants to get warm. He looks around but sees no inhabited place, so he keeps walking forward. Suddenly, he sees a bonfire a short distance from the path. Then, the heat of the bonfire, which he imagines

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> can warm his body, moves him to interrupt his walk (as if the fire itself were pulling him) and becomes the motive behind his behavior. The hiker then heads toward the bonfire (Leontiev, 1961, p. 346, our translation)

Beyond motives, the concept of activity also underpins the teacher's work in structuring instruction. The Teaching Guiding Activity (AOE) is grounded in the assumptions of cultural-historical theory and emerges as an alternative for conducting educational activity based on historically and socially produced knowledge. Through the AOE, a dynamic process is established, one that involves content and socio-historical knowledge produced by humanity, whose aim is the appropriation of theoretical knowledge and whose object is the formation of students' theoretical thinking (Moura *et al.*, 2010). The next section presents the methodological aspects and structure of the research concerning the teaching and learning process in mathematics and the process of measurement.

3 Methodological Aspects

Considering the political-philosophical dimension of the research, historical-dialectical materialism is adopted as a fundamental premise of contradiction (Triviños, 1987; Marx, 2013) and as a means of overcoming the limitations of "learning to learn" (Duarte, 2001b), formal logic, and empirical thinking (Davydov, 1988; Rubtsov, 1996). Historical-dialectical materialism was chosen because educational processes are understood as historically situated, and the analysis of the object is realized through the dialectical process of contradiction and movement. Thus, the human being and their intentional activity through labor are understood as capable of transforming both reality and themselves (Moretti, Martins & Souza, 2017).

Accordingly, the theoretical and methodological foundation of the research is the Teaching Guiding Activity (AOE), which incorporates the historicity of knowledge, helps teachers go beyond superficial educational phenomena, and promotes modes of appropriation and creation of resources for the full development of students' potential. It is important to emphasize

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that the AOE is an intentional act that integrates actions, operations, and objectives into its activity, and considers school education as responsible for the learning of scientific concepts and the development of theoretical thinking (Moura *et al.*, 2010).

Therefore, the method applied in this study was the formative experiment, defined as "the study of the particularities of experimental teaching organization and its influence on the psychic development of students [...]" (Davydov, 1988, p. 195, our translation). This method essentially involves studies and the experimental creation of conditions that foster the emergence of psychic phenomena (Davydov & Márkova, 1987).

The research was developed through the intervention of the teacher-participant during the course Local Exhaust Ventilation, offered at a public institution in São Paulo, involving twenty-two students enrolled in a technological undergraduate program. A total of twelve synchronous online meetings were held due to the COVID-19 pandemic. However, this article presents the study process related specifically to measurement, focusing on sessions E5, E7, and E8, during which the formative experiment was carried out based on the assumptions of cultural-historical theory in the field of mathematics and grounded in the theory of human activity. The activity analyzed in this article aimed to demystify the act of measuring and to transcend the utilitarian and individualized nature of measurement typically associated with common workplace instruments.

Throughout the formative experiment, a Triggering Learning Situation (SDA) was implemented, designed to elicit the learning motives attributed by students. It was structured into three stages: a utilitarian stage, in which students were required to use a graduated ruler to measure the lengths of five different pieces, in both decimal and fractional units; a contradictory stage, in which the students' measurement results were discussed and a contradiction was intentionally introduced — the inadequacy of the instrument to measure one of the provided pieces (F5); and an awareness stage, which involved discussions, a collective synthesis proposal to solve the

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measurement of piece F5, initially based on deduction and later grounded in socio-historical mathematical knowledge from ancient civilizations, within a teaching and learning process driven by the dialectical ascent from the abstract to the concrete (Davydov, 1988).

The study was approved by a research ethics committee, and participants provided informed consent. Data were collected through various instruments, including written production (WP), questionnaires (Q), semi-structured interviews (SSI), unstructured interviews (UI), and direct observation (DO) by the teacher-participant, enabling triangulation of data and minimizing subjective interpretations and individual biases (Gil, 2007). Material resources included audio recordings, field journals, study tasks,[5] internet connection, computers, printers, collaboration apps, and file-viewing software.

Regarding the confidentiality and specificity of the data collection, an individual and group coding system was developed: for example, (E1, G1, Alves, 09/10/21, SSI) and/or (E2, P1, Heleno; G4, Patrícia; G1, Andrade, 09/10/21, Q). The abbreviation E refers to the session number; G indicates the group, followed by a fictitious name; the date refers to the meeting; and the final abbreviation represents the data collection method (SSI for semi-structured interviews; Q for questionnaire). The teacher-participant was exclusively coded as P1, with the fictitious name Heleno.

Thus, the motives attributed by students in each stage of the study were investigated through a continuous dialectical movement between observation and transformation, the abstract and the concrete, the general and the particular, all within a vocational school context marked by deep contradictions and resistance to change, historically influenced by the hegemony of empirical thinking.

[5] Study tasks refer to specific learning activities developed and completed by students throughout the formative experiment.

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4 Data Analysis: Motives Attributed by Professional and Technological Education (EPT) Students

The analysis is based on the delimitation of the object of study through the concept of the isolated, understood as a fragment selected by the observer from a broader totality (Caraça, 1951). In this case, the predominant isolated is the meaning of contradiction,[6] intentionally planned by the teacher through the organization of the teaching activity. From this isolated, the study analyzes the “actions that reveal the process of formation of the subjects participating in an isolated” (Moura, 2000, p. 59, our translation), which is defined as an episode. In the present study, Episode 2 is titled motives of the (un)conscious, as it contains analyses of the students’ actions and operations related to both empirical and theoretical thinking. Finally, by analyzing the object of study in movement and its interdependence with the elements of those actions, integrated with the motives, two scenes are presented: Limitations of Empirical Thinking and Dichotomy Between Scientific Thinking and Know-How.

4.1 Scene 1 – Limitations of Empirical Thinking

In meeting E5, students were introduced to the first (utilitarian) stage of the Learning Triggering Situation (SDA), which consisted of habitual operations involving the use of a nonstandard graduated ruler. The goal was to measure, using the instrument provided and illustrated in Figure 1, the lengths of five pieces drawn on paper (F1, F2, F3, F4, and F5).

[6] The contradiction elicits the student’s meaning, which is identified in the analysis of the dialogues or intentionally prompted by the teacher through the Learning Triggering Situation (SDA). According to Leontiev (2004), meaning is defined as a relation between what stimulates (motive) and what guides (object) the individual in their action.

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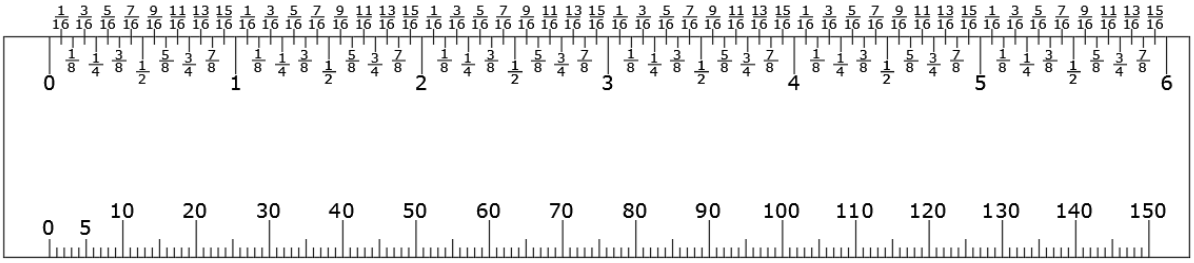
Figure 1- Graduated ruler: decimal and fractional scales



Source: Arruda (2024, p. 381)

Both the ruler and the pieces were drawn by Professor Heleno using AutoCAD software, which is specifically designed for creating technical drawings. The files were then exported in electronic format with their respective dimensions and proportional scales. Students received the electronic file with the goal of printing and completing the first (utilitarian) stage of the SDA, which proposed the measurement of the pieces' lengths using the nonstandard graduated ruler and submission of answers through an online form containing five questions and multiple-choice options, available at: https://forms.office.com/r/idNSc5gqxs.

Fifty minutes were allocated for printing the file, completing the individual practical task, and filling out the online form. Out of twenty-two students, fourteen participated in this phase, whose intent was a faithful reproduction of routine measurement operations in professional practice. During this stage, Professor Heleno was available for any questions, though no significant occurrences were reported. After students submitted their answers, Table 1 was compiled.

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Table 1- Results of the measurements performed

Questions	Q1	Q2	Q3	Q4	Q5
PIECES	F1	F2	F3	F4	F5
ANSWERS (TEMPLATE)	1(16/16)	31	1/2	61	none
Alberto	25	OK	12	OK	OK
Alves	OK	OK	none	OK	70,5
Carlos	OK	OK	OK	OK	OK
Damião	OK	OK	OK	none	OK
Eraldo	none	OK	none	OK	70,5
Felinto	OK	OK	OK	none	OK
Felisberto	OK	OK	OK	OK	OK
Ivalda	OK	OK	OK	OK	OK
Jesus	OK	OK	OK	OK	OK
Jeremias	OK	OK	OK	OK	70,5
Patrícia	OK	OK	OK	OK	OK
Rinaldo	OK	OK	OK	OK	OK
Silvio	OK	OK	OK	OK	OK
Vilmar	OK	OK	OK	OK	70,5

Source: Arruda (2024, p. 229)

In meeting E7, Professor Heleno presented Table 1 to the students and opened a discussion on the convergent and divergent results in relation to the official answer key. The goal of the second (contradictory) stage of the SDA was to identify what motives led students to obtain results that either aligned or did not align with the actual lengths of the pieces. Intentionally, the measurement of piece F5 was designed to be impossible to determine exactly, as a way to analyze and discuss students' responses based on possible formal logic deductions.

A preliminary analysis of Table 1 shows that most participants correctly answered the questions without prior instruction, indicating early evidence[7] of habitual measurement operations motivated by tacit knowledge — knowledge acquired through experience, which is "constituted by things we know but cannot explain, being ephemeral and always prone to error" (Duarte, 2001b, p. 99), and commonly found in professional practice. In the case of answers that diverged from the official answer key during the contradictory stage, discussion began with student Eraldo's statement about his reasons for mismeasuring one of the pieces:

[7] The evidence highlights the students' operations and actions in relation to either effective or perceived motives.

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> Hey professor, I saw it, I was doing nothing at work, and thought I'd do it quickly. I didn't even know what I was supposed to do. I just thought, 'it must be just measuring.' I didn't attend the class you gave, right, professor? I just saw that it looked like it was in millimeters (E7, G2, Eraldo, 10/18/21, UI).

Eraldo's response reveals a contradiction between two contexts he was simultaneously navigating: the in-person work environment and the online school environment. Because the class was held online, the student was inclined to engage in non-school-related activities, making the measurement task only a perceived motive (Leontiev, 1961), whether due to distraction or lack of engagement in the teaching-learning process. However, students Anacleto and Andrade pointed to a different possible reason for the measurement error:

> Anacleto: "The guy didn't know how to measure, professor [laughs]."
> Andrade: "It was a guess."
> Heleno: "A guess? You didn't know how to measure, just guessed..."
> (E7, P1, Heleno; G1, Anacleto; G1, Andrade, 10/18/21, UI)

According to Anacleto and Andrade, the motive was related to the lack of knowledge about how to read and measure using fractional divisions on the instrument, which would have resulted in the dimension 1(16/16). This same motive also helps explain student Alberto's measurements, as he misread the fractional values at the top of the ruler and instead deduced approximate values from the decimal graduation at the bottom. Table 1 shows that, for piece F1, Alberto marked twenty-five (25) units, and for F3, twelve (12) units.

Alberto was driven by empirical thinking when he made deductions to estimate approximate lengths and confirm measurement results. According to Moura *et al*. (2010), the act of deduction is characteristic of empirical thinking, especially when the phenomena or attributes of an object cannot be directly observed and must be inferred (Moura, 2010). This process of deductive action repeated when students Alves, Eraldo, Jeremias, and Vilmar measured piece F5 and marked seventy and a half (70.5) units, as shown in Table 1.

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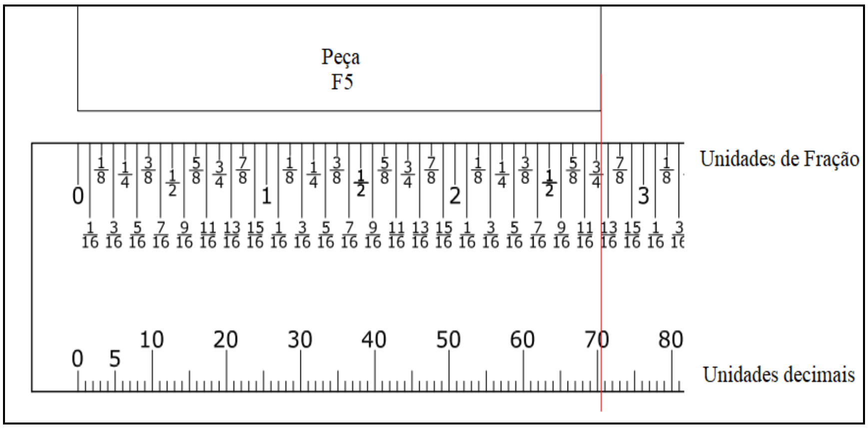
Professor Heleno had intentionally designed piece F5 so that its exact length could not be measured with the conventional graduated ruler. Figure 2 illustrates the red line that shows the instrument's imprecision when used to measure piece F5.

Figure 2- Result of the measurement of piece F5



Source: Arruda (2024, p. 234)

This condition — a contradiction between the ruler's scale and the object's dimension, intentionally introduced by Professor Heleno — led to additional deductive actions motivated by empirical thinking. This is evident when students Alves and Rinaldo assert that their result was 70.5 units, although the correct answer was "none of the above," given the ruler's limitations.

> Alves: "Mine came out as seventy point five here."
> Heleno: "So some people put seventy point five, what do you think?"
> Rinaldo: "Mine matched exactly. Seventy point five."
> Alves: "But the right answer is 'none of the above,' right?"
> (E7, P1, Heleno; G1, Alves; G4, Rinaldo, 10/18/21, UI)

Then, Professor Heleno tried to explain and visually demonstrated, using Figure 2, the impossibility of stating an exact value, since the ruler's scale lacked the necessary divisions to determine the actual length of piece F5.

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> Because... Let's see here, ok? I have an instrument that has a division at the bottom, "one unit," right? Divided by a hundred, one unit into a hundred parts. Let's not call it millimeters because this ruler isn't in millimeters. It's divided, there are a hundred divisions corresponding to one unit. So when you go to measure the piece, what happens? Let's place it here, right? So when you measure the piece, does this happen? [The professor shows the dimension of piece F5 measured with the ruler, where the red line falls between seventy and seventy-one.] Yes, or no? (E7, P1, Heleno, 10/18/21, UI).

Collective discussion and reflection (Rubtsov, 1996) on deductive actions (Moura, 2010), as well as the teacher's mediation during the teaching-learning process, appeared to trigger an initial movement toward conscious awareness (Leontiev, 2004) of the object of study. In the following dialogue, Professor Heleno highlights this contradiction and directly challenges Alves' empirical thinking. However, the students' collective actions stimulate theoretical thinking in Rinaldo and Eraldo, who, by overcoming deductive action, were now motivated by abstract reasoning about the ruler's arithmetic limitations.

> Alves: "So, that's what happened here, right? Mine showed the halfway mark."
> Heleno: "Could I assert that the value is seventy point five? That's the question."
> Rinaldo: "You can't say that because the ruler doesn't have that mark. There's no graduation between seventy and seventy-one where we could be certain it's seventy point five." (E7, P1, Heleno; G1, Alves; G4, Rinaldo, 10/18/21, UI)
> Eraldo: "You make a deduction based on the values shown, right, professor? You see seventy point five, two and three quarters inches, two and three sixteenths, and so on. But logically, this instrument doesn't have the resolution, so it couldn't be that, right?" (E7, G2, Eraldo, 10/18/21, UI).

Both Rinaldo and Eraldo point out the lack of arithmetic subdivisions needed to precisely measure piece F5. Eraldo also recognizes the process of deduction and concludes that the instrument lacks the necessary divisions. Moreover, the collective activity strategically organized by Professor Heleno to discuss the students' answers served as a deliberate means of using contradiction—between the deduced result (70.5) and the ruler's limitations—to

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foster the development of higher psychological functions (Vygotsky, 2007). Essential elements of collective activity include the exchange of modes of action, mutual understanding, communication, and reflection to overcome the limitations of individual actions (Rubtsov, 1996).

Empirical thinking, as identified in the data analysis for Scene 1, emerged as an effective motive (Leontiev, 1961) and the primary one among students. However, it can generate limited awareness and lead to disengagement from the learning of a concept. Empirical thinking reinforces habitual operation and deductive action and can justify itself as an effective motive by treating scientific knowledge as perceived but often unnecessary. It is important to note that habitual operation and deductive action stem from a process of alienation in the work context. In professional tasks, deducing an object's measurement, even when using an unsuitable instrument, may not affect the final outcome. This implies that many workplace practices reinforce empirical thinking, and when scientific knowledge is introduced at school, a natural contradiction arises. It is the teacher's responsibility to organize teaching activities and mediate learning situations that raise students' awareness of the alienation present in the work context and emphasize the need to overcome empirical thinking.

4.2 Scene 2 – Dichotomy Between Scientific Thinking and Know-How

Still in meeting E7, Professor Heleno intentionally initiated the third stage (awareness) of the Learning Triggering Situation (LTS) through a collective activity (Rubtsov, 1996) lasting one hundred minutes, with seventeen students in attendance. The professor created online breakout rooms and divided the students into four groups to discuss the following question: What solution does the group propose to obtain the exact value of the piece (F5), considering the same graduation of the instrument (ruler) provided in the piece measurement task?

Professor Heleno intentionally refrains from providing any guidance regarding the possible solution to the problem. However, the discussions reveal that students appropriated the concept of subdivisions, including

Alberto, who had made estimations in the first stage, and easily proposed a solution to the measurement problem:

> Andrade: He [the professor] included the piece because of lack of precision.
> Anacleto: Exactly, there's no way to measure the piece precisely, because the ruler, the instrument provided, doesn't have enough gradation to make an exact measurement, right?
> Alves: The ruler doesn't have the correct graduation.
> Anacleto: Alberto posted it there. [In the chat: The provided ruler lacks precision due to insufficient graduation]. In other words, the ruler doesn't have enough gradation for an exact measurement. (E7, G1, Andrade, G1, Alberto, G1, Alves; G1, Anacleto, 10/18/21, WR)
> Damião: Would it be the case that, using the same ruler, we make more subdivisions in it to get a more exact, more accurate value? Heleno: There it is! A new idea just came up! That's the direction, okay?
> Eraldo: The subdivisions.
> (E7, P1, Heleno, G2, Damião, G2, Eraldo, 10/18/21, WR)

Considering the development of the teaching process up to this point, the students' dialogues suggest evidence of three fundamental conditions of learning related to solving the problem of measuring the length of piece F5: the promotion of discussion through collective activity (Rubtsov, 1996); the effective motive (Leontiev, 1961), based on the concept of measuring length through the appropriation of arithmetic subdivisions; and the teacher-organized and mediated learning activity, grounded in the Teaching Guiding Activity (AOE) (Moura, 2010).

In meeting E8, aiming to continue the teaching and learning process based on the AOE, the professor presented an overview of the historical-cultural perspective and the measurement solutions used by ancient civilizations through mathematics. He gave examples such as finger counting, grouping, and the use of geometry to demarcate land in Egypt (Boyer, 2012), as well as the emergence of numbers due to the need to quantify objects and animals (Rocho *et al.*, 2018). The professor also reinforced the concept of measurement (Caraça, 1951), relating it to aspects of arithmetic and geometry, among other examples of concepts such as measurement and density, comparing the students' proposed solutions to those of ancient civilizations.

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Continuing with the third stage (awareness) of the LTS, the professor initiated a discussion and asked participants to share examples of measurements in work situations where the process of measurement and other mathematical aspects, now from a historical-cultural perspective, would be present. Student Andrade responded:

> I've got an example, maybe it sounds crude. But I use the palm of my hand, which measures 24 centimeters. When I don't have anything to measure with, I do this. (E8, G1, Andrade, 10/25/21, UI)

According to Caraça (1951, p. 29, emphasis in original, our translation), measuring "consists in comparing two quantities of the same kind — two lengths, two weights, two volumes, etc." In Andrade's example, he compares a standardized length measure from the International System (SI) — centimeters — to the size of his palm. Moreover, he uses his palm as a reference tool when no measuring instruments are available, which mirrors the practices of ancient civilizations. This reflects a sense of awareness about the historical-cultural perspective of length measurements, as practiced by early societies who used parts of the human body — foot, inch, cubit, etc. — as references (Rocho *et al.*, 2018). In another interesting example concerning the concept of measurement, Andrade explains:

> To get a liter of oil, I weighed the water. I put one liter of water into a container, weighed it, that is, one kilogram, and that container gave me the volume of one liter. Then I used that volume to measure one liter of oil (E8, G1, Andrade, 10/25/21, UI).

In this second example, Andrade needed to measure one liter of oil. By using scientific knowledge about the properties of water, such as weight, density, and volume, he obtained an approximate volume for the oil. He understood that water and oil have considerably different densities, yet the mass and volume (1 kg/m^3) of water are universal references for measuring quantities of the same kind (Caraça, 1951), meaning they can be used as a

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reference for measuring other substances based on geometric volume. Andrade's conscious action (Leontiev, 2004) is driven by theoretical thinking, and his analysis reveals an understanding of both the external and internal properties of objects.

Andrade's explanation and participation in the collective activity encouraged questions and clarifications from other students, stimulating participation and transforming scientific and mathematical knowledge into an effective motive (Leontiev, 1961), as the following dialogues show:

> Felisberto: But isn't the density different, Andrade? Just to be sure. Isn't the weight of water different from oil? Isn't that right, professor, or am I mistaken?
> Andrade: So, I used the volume, right? I measured the volume. If I weighed the oil, it would give a different weight, right? I weighed one kilo of water, put it into a container, and that gave me a liter of volume. I marked that graduation, and when I poured the oil, it gave me one liter of oil. But if I weighed the oil, it would have a different weight, right? Got it?
> Felisberto: Got it, got it. Perfect.
> (E8, G1, Andrade, G2, Felisberto, 10/25/21, UI)

> Anacleto: Oh, but I've got a question about this thing, because like, oil is denser, right? Thicker than water? So did that one liter of water match one liter of oil? I'm gonna try that now, I'm curious.
> Andrade: I used a container. Volume and density are different, right? Same thing as if you took a kilo of styrofoam, it would take up much more space, right? Something like that.
> Rinaldo: The exact measure is the liter, that's what he wanted. He weighed one kilo of water, and one kilo of water is exactly one liter, right, Andrade? Then if you've got a one-liter container, whatever you put in there will be one liter.
> Andrade: Exactly, anything I put in will be one liter. It just won't weigh the same.
> Rinaldo: If you take a one-liter bottle and put soda in it, it's one liter of soda. Water? One liter of water. Oil? One liter of oil. The weight's different.
> Andrade: That's it!
> (E8, G1, Andrade, G1, Anacleto, G4, Rinaldo, 10/25/21, UI)

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Following this discussion, and now adding a real work situation, students Felisberto and Patrícia, motivated by the concept of measurement (Caraça, 1951), also shared:

> Felisberto: Professor, at my job, we use the door. When we get a drawing without a scale, we use the doors. For example, standard doors are a reference to scale the entire drawing. Sometimes I need to draw... like, we get really old architectural drawings made by hand. Then I know — sometimes I measure the drawing with a scale ruler, and the door is 80 cm. But the dimensions of the other objects aren't there. So I use the door as a reference to scale all the other objects. To figure out their dimensions. So far it's worked! [...] I've seen a lot of old stuff that doesn't have all the dimensions, and then you go by it, it's like a rule of three [...]
> Heleno: That's great! Patrícia says she does the same thing [in the chat: I do that too, Felisberto; I use the door as a reference, lol.]. The door as a reference. Cool, right?
> (E8, P1, Heleno, G2, Felisberto, G4, Patrícia, 10/25/21, UI)

In this case, the problem is an old architectural drawing without measurements — something common in the workplace. Since architectural plans are typically drawn to scale and the door size is a standardized reference, knowing its measurement allows them to estimate the dimensions of other objects using a simple rule of three. This reasoning relates to proportionality, a mathematical practice already present in Mesopotamian civilizations (Radford, 2011). The discussion about proportionality and the rule of three also motivated student Jeremias, who explained his work method based on conscious action (Leontiev, 2004):

> If you have a reference, you can use the rule of three and find the exact measurement of the piece. Actually, I do this a lot, you know? That's what I'm saying, okay? I use the rule of three. It works. If you have a known measurement, let's say you have a piece and you know its size, you measure it with the provided ruler, and let's say it gives you fifteen. If that piece measures twenty, then fifteen equals twenty, and whatever else you measure equals X. Then you'll get the exact size of the unknown piece, using the ruler (E7, G3, Jeremias, 10/18/21, WR).

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Science and mathematics education in Professional and Technological Education (EPT) can foster the development of theoretical thinking by triggering students' effective motives (Leontiev, 1961) during classroom discussions. Scientific and mathematical concepts such as measurement, density, volume, and the rule of three are easily appropriated in a school context that integrates scientific knowledge with real-world work practices. This integration enhances the student's motivation in technical areas and creates opportunities to overcome empirical thinking.

> The appropriation of scientific knowledge by the subject enables them to comprehend new meanings of the world, broaden their perceptual horizons, and modify how they interact with their surrounding reality; in short, it allows them to transform the form and content of their thinking (Rosa, Moraes & Cedro, 2010, our translation).

This condition of integration and the awakening of students' effective motives also result from the teacher's organization of teaching activity — pedagogically planning the teaching-learning process in a strategic movement of utilization, contradiction, and awareness, reinforced by the historical-cultural perspective of the content and the concept of measurement. According to Davydov (1988), when students operate with concepts, they develop theoretical thinking by reproducing the idealized object and understanding its system of relationships and universal forms.

5 Final Considerations

The motives for learning initially identified in the context of using the graduated ruler encompass objective and deductive operations driven by immediate results, professional experience, and empirical thinking. In a second moment, intentionally promoted through the teacher's organization of the teaching activity, the sense of contradiction stands out between logical deduction and historically produced knowledge, the latter based on the emerging awareness of arithmetic aspects embedded in the instrument. The motives for students' awareness of certain scientific and mathematical concepts, including the concept

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of measurement, involved the analysis of the object of study in terms of its external and internal properties, historical development, and scientific concepts strengthened through collective activities.

Other motives were also identified through data analysis, such as lack of commitment, disinterest, or lack of knowledge; all of which also stem from contradictions between the contexts of work and school. On the other hand, the SDA, intentionally planned and associated with teacher mediation in the teaching and learning process, proves highly relevant, as students are initially encouraged to perform habitual measurement operations and are later challenged by their own deductions and prompted to propose a solution for measuring piece F5, which led to the suggestion of subdividing the ruler's scale. In this process, the teacher clarifies the concept of measuring and the historical-cultural knowledge embedded in the measuring instrument. Students' primary motive then begins to consider scientific knowledge, as they appropriate historical-cultural concepts and share examples of their application in work situations integrated with theoretical knowledge.

In the context of work and Professional and Technological Education (PTE), the general rule is to achieve results, and the instrument is treated as an end in itself, that is, solely in its utilitarian aspect. The SDA, intentionally designed and implemented, takes students beyond practical application, encouraging them to explore the internal properties of the object and appropriate the historical-cultural concepts involved in its creation. The evidence presented in this study points to the main stages of the teaching and learning process: habitual operations and deductive actions by students; the collective activity and the creation of ruler subdivisions influenced by teacher mediation; and the moment of awareness, when students exemplify, through work-related situations, their growing understanding of internal and external object properties through the concept of measurement.

Thus, the study concludes that the teaching and learning process of science and mathematics in PTE, grounded in historical-dialectical materialism, the cultural-historical theory, and the theory of activity, can identify the alienating

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and limiting conditions experienced by students and transform their motives for learning into effective ones. Through the pedagogical organization of teaching activity and the teacher's intentionality, the sense of contradiction breaks the boundary between empirical and theoretical thinking. In other words, it enables the exploration of the historically embedded knowledge behind work instruments and the deductive actions involved in measurement, going beyond utilitarian application. The student moves from a position of mere use to one of creation, making it possible to understand the historical development of the instrument, overcome strictly empirical thinking, and assign meaning and motives to scientific knowledge.

Razones para aprender y superar el pensamiento empírico en el análisis de un proceso de medición

RESUMEN
La investigación tuvo como objetivo investigar los motivos atribuidos por los estudiantes durante un proceso de enseñanza y aprendizaje basado en la apropiación del concepto de medida. Se justifica por el hecho de que las políticas educativas brasileñas fomentan prácticas asociadas al pensamiento empírico. Se basa en el materialismo histórico-dialéctico y en las concepciones teóricas de los psicólogos y científicos rusos. Participaron de la investigación veintidós estudiantes de un curso superior de tecnología de una universidad pública de São Paulo. Como procedimiento metodológico se utilizó un experimento formativo organizado en tres etapas: utilitaria, contradictoria y de concientización. Se encontraron evidencias sobre las acciones de deducción y concientización de los estudiantes motivado, respectivamente, por el pensamiento empírico y la concientización al reconocer las propiedades internas del instrumento y fundamentar acciones a través de aspectos de aritmética y geometría. Se concluye que la superación del pensamiento empírico depende de los motivos efectivos del estudiante mediados por la organización de la actividad docente y los momentos de interacción del docente.

Palabras-clave: Concepto de medida. Matemáticas. Motivos. Pensamiento empírico.

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