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Planning Mathematics Teaching Activities with Educational Robotics: the centrality of teacher reflection through a Historical-Cultural lens

Planejamento de Atividades de Ensino de Matemática com Robótica Educacional: a centralidade da reflexão docente sob lentes Histórico-Culturais

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ABSTRACT
This article discusses the centrality of teacher reflection in the planning of Mathematics Teaching Activities. This process is mediated by teachers who collectively develop study tasks, using educational robotics as a cultural instrument in teacher-student interaction. Considering the Historical-Cultural Theory, it is argued that teacher training requires understanding of how pedagogical practice is constituted by social and mediated processes. We explore Leontiev's Activity Theory, highlighting human action as a hierarchical system driven by motives and objectives, and how its contradictions stimulate reflection. Teaching Activity from Davydov's perspective is presented, highlighting the fundamental role of the teacher in the elaboration of study tasks that aim at the development of theoretical mathematical thinking. Teacher reflection is analyzed as a higher

RESUMO
Este artigo discute a centralidade da reflexão docente no planejamento da Atividade de Ensino de Matemática Esse processo é mediado por professores que, coletivamente, elaboram tarefas de estudo, utilizando a robótica educacional como instrumento cultural na interação professor-estudante. À luz da Teoria Histórico-Cultural, argumenta-se que a formação docente requer uma compreensão de como a prática pedagógica se constitui por processos sociais e mediados. Exploramos a Teoria da Atividade, de Leontiev, destacando a ação humana como um sistema hierárquico impulsionado por motivos e objetivos, e como suas contradições estimulam a reflexão. A Atividade de Ensino na perspectiva de Davydov é apresentada, destacando o papel fundamental do professor na elaboração de tarefas de estudo que visam o desenvolvimento do pensamento teórico matemático. A reflexão docente é analisada como função psicológica superior,

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psychological function, linked to social interaction and mediation by instruments. A planning episode between teachers illustrates how the mismatch between the expected programming and the action of the Botley robot, mediated by dialogue, boosted the organization of actions and deepened the understanding of the use of educational robotics in the teaching-learning process of Mathematics. It is concluded that reflection is the core of teacher training that aims to promote the integral development and theoretical mathematical thinking of students.

Key words: Historical-Cultural Theory. Botley Robot. Activity Theory.

ligada à interação social e mediação por instrumentos. Um episódio de planejamento entre professoras ilustra como o desencontro entre a programação esperada e a ação do robô Botley, mediada pelo diálogo, impulsionou a organização das ações e aprofundou a compreensão sobre o uso da robótica educacional no processo de ensino-aprendizagem da Matemática. Conclui-se que a reflexão é o cerne de uma formação docente que visa promover o desenvolvimento integral e o pensamento teórico matemático dos estudantes.

Palavras-chave: Teoria Histórico-Cultural. Robô Botley. Teoria da Atividade.

1 Introduction

Teacher education has been established as a field of investigation that intrinsically values reflective, collaborative, and contextualized practices. In a contemporary educational context—characterized by the rapid introduction of digital technologies and the growing adoption of active methodologies (Moran, 2018) —the integration of innovative devices such as educational robots emerge as an invaluable tool. These technologies serve as instruments that enhance meaningful learning, benefiting both students in their developmental paths and preservice teachers, who require experiences that prepare them for the challenges of the 21st century.

Education in the present century is a constantly reconfiguring field, deeply influenced by the growing presence of digital technologies. From the perspective of Historical-Cultural Theory, these technologies are not merely neutral tools, but cultural instruments that mediate human relations with the world and, consequently, restructure higher psychological functions (Silva, 2023; Silva; Javaroni, 2024). They become central elements in teaching and learning activities, requiring that teachers and students not only incorporate them into the teaching-learning process, but also reflect on how they mediate individual development and the appropriation of knowledge.

In this context, educational robotics emerges as a powerful cultural instrument. It is not limited to developing technical skills, but through its practical

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and interactive dimension, it promotes the construction of meaning and the appropriation of intellectual tools. By allowing students to manipulate, program, and control robots, robotics provides a context for mediated activity (Vygotsky, 2014, Volume II), in which social interaction and language—whether verbal, bodily, or programming—become essential for problem-solving and the development of computational thinking.

It is essential to understand that computational thinking, from this perspective, goes beyond a set of programming techniques; it constitutes itself as a higher psychological function, socially developed. According to Silva (2023), computational thinking, in the light of the historical-cultural theory, is

> a strategy for organizing thought to solve and formulate problems, based on the knowledge and practices of Computer Science—such as decomposition, pattern recognition, algorithm, and abstraction—when the culture of this field of knowledge is incorporated into one's social relations (p. 288, our translation).

It is precisely in this process of appropriation and internalization that the practice with educational robotics reveals its broader pedagogical potential. This activity, mediated through the interaction between the teacher and students using educational robotics as a tool, creates a dynamic environment in which individuals not only manipulate objects but also engage in complex communicative exchanges. It is through language—whether in discussing strategies to program the robot, negotiating roles within the group, or verbalizing discoveries—that concepts take shape and are internalized. Social interaction thus becomes the driving force of learning, where collaboration, debate, and the exchange of perspectives on the use of the prototype enhance knowledge production and the overcoming of individual challenges.

> Thus, the use of robots in education emerges within a scenario of changes in the way of learning and, consequently, in the way of approaching education. What guarantees this is the development of computer science and its tools, especially the internet. These changes brought about by the emergence of a connected society are neither neutral nor isolated; they also affect the school and its way of perceiving education (Brito; Moita; Lopes, 2018, p. 32, our translation).

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At the core of this approach lies the understanding that human development occurs through mediated activities (Vygotsky, 2014, Volume I, II, III, IV, V, VI). It is not digital technology itself that generates learning, but rather the way it is used in interactions and how these interactions are permeated by language. Social interaction, according to Vygotsky (2014, Volume II), is the driving force of development, as it is through it that individuals internalize the cultural ways of thinking and acting. Language, in turn, is not merely a means of communication, but the primary system of semiotic mediation that allows the subject to organize their thinking, plan their actions, and construct shared meanings (Vygotsky, 2014, Volume II).

In the context of educational robotics, this is manifested in discussions about how to control the robot, in the negotiation of strategies to solve a challenge, in the explanation of the mathematical concepts involved, and even in the mistakes that become opportunities for collective learning. The teaching activity and the learning activity with educational robotics, therefore, are intrinsically social and mediated—a microcosm in which learning occurs through the dynamics of relationships and the appropriation of symbolic and cultural tools.

In Basic Education, in particular, educational robotics takes on an even more significant role. Its ability to provide concrete and challenging experiences allows students to act within their Zone of Proximal Development (ZPD). According to Vygotsky (2014, Volume II), the ZPD represents the relationship between the student's actual level of development (what they can do independently) and their proximal level of development (what they can do with the help of a more experienced human being, such as the teacher or peers).

In this sense, educational robotics, as a cultural instrument, along with the mediation of the teacher or peers, drives the student to overcome challenges they would not be able to face alone, promoting the formation of new scientific and mathematical concepts and skills in a culturally mediated way, encouraging exploration and discovery throughout the student’s school journey.

Considering the above, this article emerges from the reflections of the first author during her doctoral internship at Utah State University, located in the

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United States of America, under the supervision of the third author. During this period, the first author had the opportunity to closely follow the teachers and teacher-researchers who were part of the research group "SPARC-Math (Spatial Activities and Robot Coding for Mathematical Thinking)," coordinated by the third author, and observe that they dedicate significant time to thinking about and organizing teaching activities with educational robotics before implementing them with students in schools.

Given this transformative potential and the complexity involved in integrating educational robotics into pedagogical contexts, it becomes essential to discuss the training of Mathematics teachers. In particular, the importance of reflective moments on teaching activities with this technology is a central theme for the improvement of pedagogical practice shaped using this tool in the teacher-student interaction.

Thus, this article aims to deepen the theoretical discussion about teacher reflection in teacher education, focusing on the use of educational robotics in Mathematics teaching. To this end, we will use Historical-Cultural Theory (Vygotsky, 2014, Volume I, II, III, IV, V, VI) as an analytical lens, with special attention to Leontiev's Activity Theory (1978) and Davidov's Teaching Activities (1988), seeking to provide support for understanding how teacher reflection can mediate the process of appropriation and development of innovative and meaningful pedagogical practices in Mathematics teaching with educational robotics.

2. Historical-Cultural Lenses: Planning the Teaching Activity and the Centrality of Teacher Reflection

In this section, we will explore the theoretical pillars that support the central discussion of this article. With a predominantly theoretical character, this work will deepen and articulate fundamental concepts of Historical-Cultural Theory (Vygotsky, 2014, Volume I, II, III, IV, V, VI), along with its developments in Activity Theory (Leontiev, 1978) and Davydov's Teaching Activities (1988). This conceptual framework will serve as the guiding thread to understand human development and learning as socially mediated processes, offering a critical lens to

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discuss the relevance of teacher reflection in the education of Mathematics teachers when planning teaching activities in the context of educational robotics.

2.1. Activity Theory: Leontiev and the Structure of Human Action

The Activity Theory, developed by A. N. Leontiev, represents a significant expansion of Vygotsky's principles, focusing on the structure and dynamics of human activity. For Leontiev (1978), rather than a mere collection of reactions or responses, the activity a dynamic and hierarchical system, driven by needs and motives manifested through actions and operations. At the core of Leontiev's theory (1961) is the understanding that the relationship between the subject and the world is mediated by instruments and signs, and that activity is always directed toward an object that provides it with a motive.

The structure of human activity can be understood as a hierarchy that interconnects the motive that drives it, the conscious goals that constitute it, and the conditions that determine the way it is carried out. In this sense, activity is the broadest and most fundamental level of the structure. It is characterized by the motive that drives it, which in turn expresses the subject's need in relation to the object (Leontiev, 1978). Although the motive may not be fully conscious at the beginning of an activity, it is further revealed and acquires meaning as the subject interacts with the object. In the context of teaching with robotics, a teacher's activity, for example, may be the pursuit of developing students' mathematical thinking, which constitutes the motive.

Action is the unit of activity that is subordinated to a conscious goal. Actions are the specific and intentional steps that the subject performs to achieve the motive of the activity. The goal is the anticipated image of the outcome of the action. If the general activity of a teacher is to teach Mathematics, one action might be planning a didactic sequence with educational robotics or guiding students in solving a geometry problem using the robot. These goals are intentional and conscious, and their realization contributes to fulfilling the broader motive.

Operations are the means through which actions are carried out, directly depending on the objective conditions in which the action takes place. They

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represent the way the action is performed and are often less conscious or become automated with practice. For example, assembling the prototype, connecting the cables, or adjusting the robot's speed are operations that support the action of implementing an activity with educational robotics. In this sense, the use of the robot is not the action itself, but the mediating instrument that enables the execution of operations that constitute the teacher's pedagogical action.

From this perspective, educational robotics is conceived as an instrument that, when used in interactions between students and knowledge, not only supports task execution but also contributes to structuring the actions and operations of teachers and students. Teaching activity, when incorporating educational robotics, is also influenced by the community in which the teacher is inserted (such as a research group or a school team), by the rules governing that community, and by the division of labor among its members.

The analysis of these Leontievian components—motive, goal, instruments, conditions, community, rules, and division of labor—is fundamental to understanding the underlying dynamics of teaching actions and the reflections that emerge from them. In this sense, Leontiev (1978) emphasizes that human activity does not occur in isolation, but is situated in a complex social context, mediated by fundamental elements, namely:

1. **Conditions:** refer to the set of circumstances and factors (internal and external) that influence the execution of operations and, consequently, of actions. In the context of educational robotics for Mathematics teaching, conditions may include the availability of robotics kits and remote controls, the class time available for assembly and programming, the limitations of the physical space, and the students' prior knowledge of mathematical concepts and robot handling. The teacher's reflection on these conditions is essential for adapting their actions and ensuring the feasibility of the activity.
2. **Community:** represents the social collective in which the activity develops and in which the subject is embedded. It is the group of individuals who share the same motive for the activity. For Mathematics teachers using

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educational robotics, this community may be the research group they belong to, the school's pedagogical team that fosters innovation, or a network of educators who discuss the use of technologies in teaching. Participation in this community provides support, exchange of experiences, and an environment for the collective production of knowledge and practices, directly influencing the teachers' actions and reflections.

3. **Rules:** are the explicit or implicit norms, conventions, and guidelines that regulate the activity within the community. In the context of educational robotics in Mathematics teaching, rules may include the curriculum of the Base Nacional Comum Curricular (BNCC), safety standards for handling equipment, guidelines for group work, or the directives of a research group.
4. **Division of labor:** refers to the way tasks and responsibilities are distributed among members of the community to achieve the common goal of the activity. In a group of teachers planning activities with educational robotics, the division of labor may involve one teacher responsible for designing the lesson plans, another for finding resources, a third for implementing the activities and observing students, and another for analyzing the results. The way work is divided affects interactions, communication, and opportunities for individual and collective learning and reflection.

Considering these elements—conditions, community, rules, and division of labor—is indispensable for a comprehensive analysis of teaching activities with educational robotics. They constitute the sociocultural environment that shapes teachers' actions, their pedagogical choices, and ultimately their reflections on practice. Understanding how these components interact with motives, goals, actions, and operations is the path to unveiling the complexity of teaching activity and teacher education.

2.2. Teaching Activity from Davydov's Perspective

Aligned with Leontiev's Activity Theory, the conception of Teaching Activity developed by Davydov (1988, 1999) offers a deep understanding of how scientific

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knowledge is appropriated by students. More than that, this perspective highlights the responsibility and centrality of the teacher in designing the teaching activity, as it is the teacher who, by planning and organizing didactic situations, creates the conditions for knowledge assimilation to occur.

For Davydov, teaching is not merely the transmission of information, but the organization of an activity in which students engage in solving theoretical problems, seeking to uncover the genesis and formation of concepts. At its core, the teaching activity aims at developing the capacity for autonomous study and theoretical thinking. In the Historical-Cultural approach, this autonomy is not an exclusively individual attribute, but is constituted and developed within collectivity.

Autonomous study, in this sense, is the capacity of a group of students, mediated by social interaction and language, to organize their actions, solve problems, and construct new knowledge collaboratively, while reflecting on their own learning process and monitoring the execution of their actions. It is the autonomy of the social subject that develops in and through mediated activity, enabling the appropriation of general methods of action for a class of problems, and not merely the solution of specific cases. To organize this activity, the teacher needs to consider specific constituent elements, such as:

1. **Need-Motive:** in the student's context, this refers to the need to understand the essence of phenomena and the origin of concepts, rather than merely memorizing information. For the teacher, in their training activity, this translates into the necessity to seek teaching methods that promote meaningful learning, mobilizing students' theoretical thinking.
2. **Study Task:** this is the central problem the student must solve, carefully formulated to require the discovery of a general method of action for a class of problems, and not just the solution of a particular case. In the training of Mathematics teachers using educational robotics, a study task for future teachers could be: "How can we use prototypes to explore the concept of angle or symmetry in a way that challenges Early Years students to discover their essential properties, and not just their definitions?" This task encourages the teacher to go beyond manipulating the device, seeking its potential for

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concept formation. This reflection is essential both for the teacher in initial training, who is learning to design and plan study tasks, and for the in-service teacher who, when planning their lessons, reflects on how educational robotics can be articulated with the cultural and social characteristics of their students, ensuring that the task is relevant and meaningful to the context in which it will be applied.

3. **Study Actions:** these are the operations and actions the student performs to solve the study task, such as analysis, modeling, transformation, control, and evaluation. For both the teacher in initial or continuing training, these actions translate into pedagogical actions that organize the student's activity. For example, modeling a mathematical problem with the prototype, transforming the proposed challenge into a sequence of commands for the robot, or evaluating whether the learning objective was achieved by observing the students' interaction with the prototype.
4. **Study Content:** this consists of generalized theoretical knowledge about the essential relations of the objects of study, not isolated facts. In Mathematics teaching with educational robotics, the content is not only the operation of the prototype or the development of computational thinking when incorporating the culture of Computer Science into social relations in the act of solving tasks. The content consists of the underlying mathematical concepts, such as those related to spatial relations, logical sequences, measurement, among others, which students appropriate through interaction with the prototypes. For the teacher, the study content encompasses both mastery of these mathematical and computational concepts and the pedagogical knowledge to effectively measure educational robotics.
5. **Control and Evaluation Operations:** these represent the student's reflection on their own learning process and the capacity to verify whether their actions correspond to the study task. In teacher training, this is evident in the teacher's reflection on their own practice of designing and planning study tasks with educational robotics. This involves evaluating

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whether the challenges proposed with the prototypes truly lead students to the formation of mathematical concepts, monitoring the students' interaction with the prototypes and with each other, and adjusting teaching strategies based on observed results.

Thus, by understanding this organization and structure of the teaching activity, the teacher fully assumes their role as the organizer of this process. In their training, the teacher is encouraged to conceive and develop learning situations in which the manipulation of prototypes and problem-solving with them are not ends in themselves, but instruments and means for students to actively and investigative form mathematical concepts.

Educational robotics, therefore, becomes an instrument for creating study tasks that demand the development of computational thinking and the application of mathematical principles, challenging students to move beyond superficial recognition toward a deep understanding of phenomena. It is at this point that teacher education must focus, fostering reflective practice regarding their teaching activity, preparing the teacher to transcend mere technique and to conceive educational robotics as an instrument present within the ZPD constituted through the interactions between teacher and students and among students themselves.

2.3. Teacher Education and Reflective Practice

Teacher reflection is recognized as an essential pillar for the continuous professional development of educators, transcending the view that pedagogical practice is merely the application of predefined techniques. It is not only about "thinking about" practice but an active and systematic process of analysis, questioning, and the constitution of new understandings regarding experiences lived both inside and outside the classroom (Schön, 1983).

From the perspective of Historical-Cultural Theory, reflection is not an isolated phenomenon; on the contrary, Vygotsky (2014, Volume II) conceives it as a higher psychological function whose development is intrinsically linked to social interaction and mediation by instruments and signs. This capacity to reflect,

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organize, and broadly and dynamically structure one's own consciousness enables the individual to internalize concepts and experiences, becoming more autonomous and aware of their actions.

Connecting with Leontiev's Activity Theory (Section 2.1), teacher reflection can be understood as a process that emerges from the contradictions and challenges inherent in pedagogical activity. When the teacher's actions do not yield the expected objectives, or when conditions (availability of prototypes, class time, etc.) or rules (curriculum, norms) impose obstacles, the teacher is compelled to reflect. Such reflection allows the adjustment of operations and actions, or even the redefinition of objectives, aiming at the transformation of the activity itself.

Thus, reflection functions as a mechanism for the development of the teacher's activity, driving the search for new motives and guiding actions toward overcoming difficulties. Interaction within a community of exchange among mathematics teachers and the division of labor in this collective (Leontiev, 1978) become privileged spaces where reflection is not only individual but also collective and shared, enriching understandings of practices—for example, those involving educational robotics.

Furthermore, aligned with Davydov's Teaching Activity (Section 2.2), teacher reflection assumes a fundamental role in the elaboration of study tasks and the organization of study actions aimed at developing students' theoretical thinking. When reflecting on how educational robotics prototypes can be used to unveil the essence of mathematical concepts—not merely to illustrate them superficially—the teacher engages in a process of appropriation of Davydov's content and methodology.

This prior reflection in planning is essential so that study tasks involving educational robotics are designed to provoke the student's need-motive, leading them toward the generalization and abstraction of knowledge. The capacity to control and evaluate one's own teaching activity, an element emphasized by Davydov (1999), requires from the teacher a continuous reflective stance that enables analysis of whether the mathematical learning objectives are being

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achieved when educational robotics is considered as an instrument in this process. Moreover, it allows for the examination of how the social interactions mediated by educational robotics are contributing to the development of students' higher psychological functions.

Teacher education, from this historical-cultural developmental perspective, requires that teachers in both initial and continuing training understand their practice as an object of analysis, transformation, and continuous improvement. In the context of using educational robotics, we engage with Schön (1983) to understand that reflection unfolds at different levels:

1. **Reflection-in-action:** occurs through immediate adjustments and decisions made during the interaction with the prototypes;
2. **Reflection-on-action:** involves the subsequent analysis of the experience, identifying successes and areas for improvement in the use of educational robotics;
3. **Reflection-for-action:** consists of planning future pedagogical interventions based on the learning gained.

In our teaching and research experiences, we have observed that within an environment constituted by the interaction among Mathematics teachers, this reflective movement is clearly perceptible, as participants relate their immediate experiences with prototypes to their preexisting school practices and to the sociocultural realities of their students, thereby enriching the analysis.

The mediation provided by colleagues, coordinators, or specialists, alongside the study tasks involving educational robotics, enables teachers to meaningfully articulate academic knowledge acquired through theoretical training with experiential knowledge derived from their lived experiences and observations in the classroom (Tardif, 2000). This integration fosters a broader, contextualized, and deeper understanding of the teaching-learning process, preparing them to develop pedagogical strategies that are more effective and adapted to the sociocultural diversity of their students. This collaborative and practical approach underscores the importance of teacher education that encourages not only critical reflection but also meta-reflection (Schön, 1983) on the teaching practice itself and its social implications.

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The promotion of reflective practice in the education of Mathematics teachers, particularly concerning the use of educational robotics, is fundamental for educators to develop a conscious, flexible pedagogical practice adapted to the challenges of the 21st century. It is through reflection that the teacher appropriates new knowledge, re-signifies their practice, and becomes an agent of transformation, capable of organizing teaching activities that genuinely promote the integral development and theoretical thinking of their students.

3. Teacher Reflection in Mathematics Teacher Education Focused on the Use of Educational Robotics

The education of teachers who teach Mathematics is a continuous and complex process that, from the perspective of Historical-Cultural theory, is intrinsically constituted in and through socially mediated practical and reflective activity. According to Bicudo (1999), such education develops through the essential articulation between theory, experience, and research. In this section, we will discuss and deepen this theme based on the observations of the first author during a research internship abroad, conducted with the SPARC-Math group.

This interdisciplinary group, dedicated to research in Mathematics Education, is composed of university professors, post-doctoral researchers, doctoral students, teachers, and undergraduate students. Despite their different initial academic backgrounds, they meet to plan study tasks focused on teaching Mathematics to students in the Early Years of Elementary School.

The choice of Mathematics as the focus area, the Early Years as the target audience, and the Botley robot was established by the SPARC research group's project. The decision to work with the Early Years audience is justified by the opportunity to develop computational thinking and logical reasoning during fundamental stages of education.

For this purpose, the Botley robot was used as a cultural instrument for educational robot coding. Botley was the main instrument chosen because it is a screen-free programmable robot that uses visual commands and a remote control.

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This makes it accessible for children, allowing students to learn the fundamentals of programming in a concrete and tactile way without needing an additional digital device, which facilitates its use in the classroom.

The objective of the group's research and discussions is to understand children's development of computational and spatial thinking, but the process of this research also reveals how involvement in collaborative planning activities, grounded in design-based methodologies, constitutes a space for teacher reflection and the professional development of Mathematics teachers. This occurs through the way such actions mobilize the principles of Davydov's Teaching Activity, placing these teachers and teacher-researchers into activity (in Leontiev's conception), thereby transforming pedagogical practice into an object of deep and continuous analysis.

The SPARC-Math group works in public schools with projects that integrate programming, educational robotics, and Mathematics. This approach goes beyond the mere use of technological resources; it organizes a Teaching Activity (Davydov, 1988, 1999) that encourages participants — teachers and researchers — to critically analyze their pedagogical practices. Such analysis manifests in reflection-in-action and reflection-for-action (Schön, 1983), articulating mathematical concepts with real and challenging classroom situations, while considering the diverse elements of the activity (Leontiev, 1978) that mediate the process. It is within this context of social interaction and mediation (Vygotsky, 2014, Volume II) that teacher reflection embedded in planning becomes a fertile ground for the construction of new teaching knowledge.

This working collective, which meets at least weekly, has as its main motives (Leontiev, 1978) the critical reflection on teaching practices in Mathematics Education, dialogue with theoretical frameworks, and the planning of pedagogical interventions using educational robotics in local public schools. This dynamic configures a community of exchange (Leontiev, 1978), where collective reflection on the Teaching Activity becomes the core of professional development.

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The methodology adopted by the group, design-based research (Cobb, Jackson, & Sharpe, 2017), is particularly relevant as it is characterized by iterative cycles of planning, implementation, analysis, and redesign of pedagogical proposals. Being the first part of preparation, the second part of observation, the third part of implementation, and the fourth part of rethinking the plan. These cycles represent privileged moments for teacher reflection, both in-action and on-action (Schön, 1983). During school interventions, the teacher-researchers initially observe classes and record the dynamics established between the observed teacher and students. These observations provide the conditions (Leontiev, 1978) for formulating study tasks (Davydov, 1988) involving educational robotics, which aim to mobilize the formation of mathematical concepts and the development of computational thinking, guiding future teacher actions.

From the planning of study tasks and group reflection on the Teaching Activity, these teacher-researchers return to the school and conduct the activity with the same students. Sessions with students are conducted by pairs of researchers, exemplifying the division of labor (Leontiev, 1978) within the Teaching Activity: one responsible for facilitating the activity (guiding the students' study actions) and the other for observing and meticulously recording the events (performing control and evaluation operations).

After each intervention, the pair meets to discuss what occurred — an essential moment of reflection-on-action (Schön, 1983) — to identify aspects for improvement and adjust the next interaction. These reports also feed the group's weekly meetings, which include video analysis of school interactions, discussion of theoretical foundations in Mathematics Education, and critical reflections on the educational robotics prototypes used. It is in this dialogical and interactive context that language (Vygotsky, 2014, Vol. II) emerges as the main mediational tool for discussing theoretical foundations and critical reflections on the use of educational robotics in Mathematics classes.

Throughout this section, the formative dynamics carried out, the organization and guiding principles of the group's work, as well as the learnings constructed by the teachers in the reflective planning process of Teaching

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Activities with the educational robot Botley will be discussed. The intention is to demonstrate how spaces like this can be configured as teacher education environments, where reflection and critical thinking about the use of educational robotics and the planning of Teaching Activity are continuously and meaningfully fostered, consolidating the teacher's role as an organizer of learning.

The Botley robot was designed as an educational solution aimed at introducing young children to the universe of programming and robotics. Weighing approximately 1.3 kg and having compact dimensions, this robot stands out for its friendly appearance, with a simple structure, bright colors, and sensors resembling expressive eyes — a set designed to attract and maintain children's interest.

Unlike many robotics kits available on the market, Botley requires no prior assembly and comes ready to use, favoring the immediate start of activities. On the other hand, this feature may limit hands-on experience with the robot's internal components, which is also valuable in more in-depth technological learning processes (Smarter Learning Guide, 2023).

An important distinguishing feature of Botley is that it does not require screen use, such as smartphones or tablets. Instead, programming is done through a physical remote control, which is advantageous in environments aiming to control children's digital screen time. Instructions are entered sequentially, allowing children to develop initial notions of logic and algorithms in a practical and playful way (Smarter Learning Guide, [s.d.]).

Despite its visual simplicity, the robot offers robust functionalities: it can detect lights, follow lines, identify objects, and perform varied movements, including precise turns. These capabilities enable children from early childhood education to explore fundamental computing concepts concretely and interactively (Smarter Learning Guide, 2023).

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Figure 1 – Botley Robot

Source: Own archive

In this context, the Botley robot was one of the resources analyzed and discussed by the group, serving as a physical instrument to catalyze teacher reflection. From the planning of a study task involving Botley, in-depth discussions emerged about programming language, computational thinking, and Mathematics teaching. This experience with Botley not only illustrates the application of educational robotics principles but also acts as a trigger for reflection on teachers' actions regarding logic, necessary pedagogical mediation, and the limitations of technology in the classroom. The next section will detail this experience, highlighting how it contributed to broadening the understanding of the teacher professional development process and the critical and reflective use of educational robotics in Mathematics Education.

3.1. An episode of reflection in the planning of the study task with the Botley robot

The collaborative dynamic previously described, which articulates theory and practice in the planning of the Teaching Activity, proved to be especially formative for the teachers, allowing the continuous construction of new meanings and appropriation of their knowledge. In one of the research group meetings, where teaching practice was constantly discussed, the participants interacted with the Botley robot based on a program they

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observed students using in the classroom. Despite involving a familiar object of study for the group, this interaction prompted new questions, such as attention to the sound emitted by the prototype during programming and the logic underlying the commands. This moment of deep observation and dialogue about Botley's functioning acted as a catalyst for reflection.

The discussion arose from an attempt to program Botley to perform a route based on the logic of the inserted commands — an action with a conscious objective. When observed in the classroom, the robot did not behave as the teacher and researchers expected. The logic was previously written on the board, and a specific behavior from the prototype was expected, but when testing the commands, the result was unexpected. This mismatch between prediction and outcome — a contradiction in the activity (Leontiev, 1978) — prompted questions about Botley's internal functioning, including the influence of sounds and execution timing on the device's response.

This moment of disruption fostered profound collective reflection among the researchers, directly impacting meta-reflection (Schön, 1983) on the physical instrument and its conditions of use. It became evident that teacher education is a continuous process nourished by doubt, listening, and joint meaning-making. Even though the prototype was familiar to the group, the episode demonstrated that technical and pedagogical knowledge is in constant development and appropriation. This movement, manifested in the teacher's ability to organize their Teaching Activity in the face of challenges imposed by reality, aiming at student development according to Davydov's (1988) principles, reflects the dynamic nature of higher psychological functions (Vygotsky, 2014, Vol. II) and the transformation of consciousness through mediated activity (Leontiev, 1978).

This episode serves as an illustration of the role of cultural tools in human activity, according to Vygotsky (2014, Vol. II). Botley, as a prototype, is not merely a passive object; its mediating function in thought and action is activated and potentiated by the mediation of another human being. The contradiction experienced — the disparity between the planned action (programming the route) and the operation executed by the robot — propelled the researchers to question their previous understandings of a particular sequencing of codes.

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The materiality of the prototype, with its physical presence and immediate responsiveness to programming, offers a tactile and interactive dimension that differs significantly from purely virtual digital technologies. This tangibility fosters engagement from those interacting with it, allowing teachers in training to manipulate, test, and directly observe the results of their actions, broadening their perception of the relationship between the sign (the logic written on the board), the tool (Botley), and the object (the expected route). Reflection, in this sense, is a goal-directed action aimed at understanding and transforming one's own activity, rather than a mere epiphenomenon.

Social interaction played a fundamental role in this reflective process. The collective discussion among the researchers, mediated by language and joint observation of Botley's unexpected behavior, enabled the development and refinement of higher psychological functions such as analysis, abstraction, and generalization. Dialogue, with its exchange of perspectives and confrontation of ideas, acted as the engine for constructing new meanings about the prototype's functioning and the conditions affecting its operation. This collaborative dynamic demonstrates how concept formation — both technical, concerning Botley, and pedagogical, regarding its use — occurs within the group's collective Zone of Proximal Development (ZPD), where knowledge is produced through peer mediation and shared experience.

The integration of educational robotics into pedagogical practice exemplifies how digital technologies become mediators in the constitution of new psychological functions and the transformation of our perception and action, mediating our relationship with the world. More than mere physical instruments, digital technologies, when incorporated into human activity, can fundamentally transform the formation of mental actions themselves, expanding the conditions for thinking and representing reality. As Silva (2023) and Silva and Javaroni (2024) argue, technology, when used as a mediating instrument in pedagogical activity, not only facilitates processes but also contributes to the development of new higher psychological functions, such as computational thinking, by demanding from the subject the logical organization of thought and the overcoming of contradictions in interaction with the world.

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From this moment of reflection, the researchers were able to collectively reorganize their future actions and operations. The deepened understanding of Botley's nuances and its interactions with environmental conditions (sounds, execution times, sequence of codes) prepared them to refine the planning of more adequate and predictable study tasks. This capacity to adjust one's own Teaching Activity based on reflection and experience demonstrates the maturation of the teachers' Teaching Activity (Davydov, 1999), who become increasingly aware of their responsibility to create conditions for the true appropriation of mathematical knowledge by students. Reflection, therefore, is not a mere complement but the very core of teacher education that seeks transformative pedagogical practice, mediated by technology and anchored in the principles of Historical-Cultural Theory.

4. Final Considerations

This article sought to deepen the discussion on the relevance of teacher reflection in the planning of Mathematics Teaching Activities, understanding it as a process that develops and is qualified through mediation by another human being, using educational robotics as an instrument in this mediation. Through the Historical-Cultural lens guiding this article, we explored the assumptions of Historical-Cultural Theory (Vygotsky, 2014, Volumes I–VI), Activity Theory (Leontiev, 1978), and Teaching Activity Theory (Davydov, 1988), concepts that interconnect to offer a robust understanding of human development and learning processes.

We reiterate that, according to Vygotsky (2014, Volume II), the development of higher psychological functions occurs through social interaction and mediation established with another human being via instruments and signs. Educational robotics, as a cultural tool, is not an isolated agent of transformation; its effectiveness is activated and potentiated by human mediation, as discussed in section 3.1. In this sense, Botley, as a prototype, is not a neutral tool; it functions as a mediating instrument of thought and action in peer interaction, expanding learning possibilities and consequently demanding a reflective stance from the teacher.

From the perspective of Activity Theory (Leontiev, 1978), we understand that teaching activity is a complex system driven by motives and objectives,

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manifested through actions and operations. Teacher reflection thus emerges as an essential process arising from the inherent contradictions within this activity, such as the discrepancy between the planned and the actual outcomes in the Botley episode (section 3.1). This reflection enables the teacher to adjust their actions and operations, and even redefine their objectives, aiming at transforming their practice. The community of exchange among mathematics teachers, who share reflections on teaching—with its rules and division of labor—functions as a fundamental environment where such reflection becomes collective and shared, enriching the appropriation of knowledge.

In line with Davydov (1988), the article underscores the centrality of the teacher in planning Teaching Activities. Teacher reflection is, therefore, indispensable for the mathematics teacher to conceive and design study tasks that genuinely stimulate students to unveil the essence of mathematical concepts, transcending the mere application of formulas or procedures. The capacity to anticipate, observe, and evaluate students' interaction with educational robotics prototypes, adjusting the Activity based on reflection, is a direct manifestation of the maturation of the teacher's Teaching Activity. The Botley example highlighted how the observation of the prototype's unexpected behavior and the subsequent dialogue led to the construction of new meanings and the reorganization of teaching actions, demonstrating a deepening of pedagogical thought development.

In sum, teacher reflection, mediated by social interaction and the use of instruments such as educational robotics, lies at the core of mathematics teacher education aimed at innovation and quality. It is through reflection that the teacher appropriates a deeper understanding of the teaching-learning process, becoming capable of organizing activities that promote the holistic development of students. The discussion and reflection proposed in this article reinforce the necessity to create and value formative spaces that stimulate critical and collaborative reflection, preparing teachers to transform their practices and confront the challenges of contemporary education consciously and grounded in Historical-Cultural Theory.

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Planificación de actividades de enseñanza de las matemáticas con robótica educativa: la centralidad de la reflexión docente bajo lentes histórico-culturales

RESUMEN
Este artículo analiza la centralidad de la reflexión docente en la planificación de actividades didácticas de matemáticas. Este proceso está mediado por docentes que desarrollan colectivamente tareas de estudio, utilizando la robótica educativa como instrumento cultural en la interacción profesor-alumno. A la luz de la Teoría Histórico-Cultural, se argumenta que la formación docente requiere comprender cómo la práctica pedagógica se constituye mediante procesos sociales y mediados. Exploramos la Teoría de la Actividad de Leontiev, destacando la acción humana como un sistema jerárquico impulsado por motivos y objetivos, y cómo sus contradicciones estimulan la reflexión. Se presenta la Actividad Docente desde la perspectiva de Davydov, destacando el papel fundamental del docente en la elaboración de tareas de estudio que apuntan al desarrollo del pensamiento matemático teórico. La reflexión docente se analiza como una función psicológica superior, vinculada a la interacción social y la mediación instrumental. Un episodio de planificación entre docentes ilustra cómo la discrepancia entre la programación esperada y la acción del robot Botley, mediada por el diálogo, impulsó la organización de acciones y profundizó la comprensión del uso de la robótica educativa en el proceso de enseñanza-aprendizaje de las matemáticas. Se concluye que la reflexión es el núcleo de la formación docente que tiene como objetivo promover el desarrollo integral y el pensamiento matemático teórico de los estudiantes.

Palabras clave: Teoría histórico-cultural. Robot Botley. Teoría de la actividad.

5 Bibliographic Reference

BICUDO, M. A. V. (Org.) *Pesquisa em Educação Matemática:* concepções e perspectivas. São Paulo: Ed. Unesp, 1999.

BRITO, R. S.; MOITA, F. M. G. da S. C.; LOPES, M. da C. Robótica Educacional: Desafios/Possibilidades no Trabalho Interdisciplinar entre Matemática e Física. *Ensino da Matemática em Debate,* [S. l.], v. 5, n. 1, p. 27–44, 2018. Disponível em: https://revistas.pucsp.br/index.php/emd/article/view/36687. Acesso em: 19 ago. 2025.

COBB, P., JACKSON, K., SHARPE, C. D. Conducting design studies to investigate and support mathematics children's and teachers' learning. In J. Cai (Ed.), *Compendium for research in mathematics education,* p. 208–233, 2017. National Council of Teachers of Mathematics.

DAVYDOV, V. V. Problems of developmental Teaching – The experience of theoretical and experimental psychological research. *Soviet Education,* 30(8), 1988. p 15-97.

DAVYDOV, V. V. Uma nova abordagem para a investigação da estrutura e do conteúdo da atividade. Trad. de José Carlos Libâneo. In: HEDEGARD, M.;

DOI: http://doi.org/10.14393/OBv9.e2025-22

JENSEN, U. J. (Org.). Activity theory and social practice: cultural-historical approaches. Aarhus (Dinamarca): *Aarthus University Press,* 1999. p. 39-50

LEONTIEV, A. N. As necessidades e os motivos da atividade. [1961]. In: LONGAREZI, A. M.; PUENTES, R. V. (orgs.) Ensino desenvolvimental: antologia. Livro I. Uberlândia, MG: EDUFU, 2017. p. 39-57.

LEONTIEV, A. *O desenvolvimento do psiquismo.* Lisboa: Livro Horizonte, 1978.

MORAN, José. Metodologias ativas para uma aprendizagem mais profunda. In: BACICH, Lilian; MORAN, José. *Metodologias ativas para uma educação inovadora:* uma abordagem teórico-prática. Porto Alegre: Penso, 2018.

SCHÖN, D. A. *The reflective practitioner:* How professionals think in action. New York: Basic Books, 1983. (Reprinted in 1995).

SILVA, E. C. Desenvolvimento do pensamento computacional em uma dinâmica pedagógica baseada na perspectiva histórico-cultural: possibilidades para a formação das ações mentais de estudantes e do conceito polígono regular a partir da produção de um pensamento geométrico. 2023. *Tese* (Doutorado em Educação Matemática) – Universidade Estadual Paulista "Júlio de Mesquita Filho", Rio Claro, 2023.

SILVA, E. C.; JAVARONI, S. L. The possible relationships between the development of computational thinking and the formation of mental actions of students in mathematics classes. *Quadrante*, v. 33, n. 2, p. 82–109-82–109, 2024.

SMARTER LEARNING GUIDE. *Botley the Coding Robot Review*. [s.d.]. Disponível em: https://smarterlearningguide.com/botley-the-coding-robot-review/. Acesso em: 5 jun. 2025.

TARDIF, M. Saberes profissionais dos professores e conhecimentos universitários: Elementos para uma epistemologia da prática profissional dos professores e suas consequências em relação à formação para o magistério. In: *Revista Brasileira de Educação*, nº13, 2000.

VYGOTSKI, L. S. *Obras Escogidas.* Madrid: Machado Nuevo Aprendizaje. 2014, Tomo I.

VYGOTSKI, L. S. *Obras Escogidas*. Madrid: Machado Nuevo Aprendizaje. 2014, Tomo II.

VYGOTSKI, L. S. *Obras Escogidas.* Madrid: Machado Nuevo Aprendizaje. 2014, Tomo III.

DOI: http://doi.org/10.14393/OBv9.e2025-22

VYGOTSKI, L. S. *Obras Escogidas*. Madrid: Machado Nuevo Aprendizaje. 2014, Tomo IV.

VYGOTSKI, L. S. *Obras Escogidas*. Madrid: Machado Nuevo Aprendizaje. 2014, Tomo V.

VYGOTSKI, L. S. *Obras Escogidas*. Madrid: Machado Nuevo Aprendizaje. 2014, Tomo VI.

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