The possible relationships between the development of computational thinking and the formation of mental actions of students in mathematics classes

As possíveis relações entre o desenvolvimento do pensamento computacional e a formação de ações mentais de estudantes em aulas de matemática

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Abstract. We present and discuss how the development of students' computational thinking can encourage the formation of their mental actions and mathematical concepts. This study draws on data from an investigation carried out with Brazilian students, aged between 15 and 16, who participated in synchronous meetings via the Google Meet platform. Using Scratch and GeoGebra software, they carried out tasks developed from the perspective of the Theory of Planned Formation by Stages of Mental Actions and Concepts, which considers that the specificities of human mental development are related to evolutionary and historical perspectives, mediated by cultural tools. From the perspective we adopted in the research, the use of words – linked to computational concepts – is important to constitute signs that will guide and control their computational practices during task-solving process, and also develop computational thinking from a cultural perspective. The contribution of this development lies in the understanding that these pillars serve as means to enable the planned formation of student's actions on the mental plane. This formation relies on guided activities that consider the student's experiences of objective reality, including the use of signs and instruments arising from the culture of computer science.
Keywords: orientation base of action; geometry; Galperin; Vygotsky; historical-cultural perspective; mathematics education.

Resumo. Apresentamos e discutimos como o desenvolvimento do pensamento computacional de estudantes pode fomentar a formação de suas ações mentais e dos conceitos matemáticos. Trazemos

Quadrante: Revista de Investigação em Educação Matemática 33(2) 82-109
https://doi.org/10.48489/quadrante.36198
Received: May 2024 / Accepted: December 2024

dados de uma investigação realizada com estudantes brasileiros, com idades entre 15 e 16 anos, que participaram de encontros síncronos por meio da plataforma Google Meet. Com o uso dos softwares Scratch e GeoGebra, eles realizaram tarefas elaboradas sob a ótica da Teoria da Formação Planejada por Etapas das Ações Mentais e dos Conceitos, que pondera que as especificidades do desenvolvimento mental humano estão relacionadas às perspectivas evolutivas e históricas, mediadas por ferramentas culturais. Na perspectiva que adotamos na pesquisa, o uso de palavras – vinculadas aos conceitos computacionais – é importante para se constituírem em signos que irão guiar e controlar suas práticas computacionais, no processo de resolução de tarefas quaisquer, e desenvolver o pensamento computacional, em uma perspectiva cultural. A contribuição desse desenvolvimento está na compreensão de que seus pilares são meios que possibilitam a formação planejada da ação do estudante no plano mental, a partir da realização de uma atividade orientada que considera as experiências da realidade objetiva do estudante, incluindo o uso de signos e instrumentos decorrentes da cultura da Ciência da Computação.
Palavras-chave: base orientadora da ação; geometria; Galperin; Vygotski; perspectiva histórico-cultural; educação matemática.

Introduction

The articulation of the development of CT (CT) in educational contexts has been the target of detailed studies carried out by researchers, in order to understand the possibilities and difficulties of this relationship. Such research has fostered the discussions initiated by Papert (1980, 1986) regarding the contributions of computing to the cognitive development of students and to problem solving.

Barcelos et al. (2015), Kalelioglu et al. (2016), Valente (2016), Shute et al. (2017), Avila et al. (2017), Santos et al. (2019), Brackmann et al. (2020), Sassi et al. (2021), Silva and Javaroni (2022), and Silva (2023) highlighted actions that promote the development of CT in students. They emphasize the importance of initiatives within the educational context to ensure that the analyzed results reach those responsible for creating guidelines and standards for education in their respective countries.

Respectively, Barr et al. (2011), Sanford and Naidu (2016), Santos (2019), Masiulionyté-Dagiené and Jevsikova (2022), and Silva and Javaroni (2024) argue that such actions are important. They argue that these initiatives need to be disseminated so that teachers can have the support to articulate the skills linked to the development of CT within their specific curricular components, encouraging students to develop this way of thinking.

Wing (2006) popularized the term CT and presented its conception, further elaborating on it in subsequent works (Wing, 2008, 2014, 2016), defining it in relation to thinking and acting within computer science. However, Disessa (2018) and Valente (2019) point out that Wing's publications do not refer studies on the impacts of computing on cognitive development that were conducted prior to Wing (2006).

Setzer (2006, n.p.) criticized the movement to integrate CT into school contexts without considering the psychological perspective on this development. He argued that such integration occurs "before the intellect is mature enough for it". According to Setzer, imposing the development of CT – defined a priori by Wing (2006) as being based on a close relationship with the way the computer scientist thinks – prior to the development of formal and abstract thinking, does not promote the involvement of feelings during observations and interactions with the environment, which are important for human development.

This perspective, which seeks to connect psychological aspects of cognition with recommendations by researchers in the field of computing, has guided our research on the subject (Silva, 2018, Javaroni and Silva, 2019, Silva et. al., 2019, Gadanidis et. al., 2022, Silva and Javaroni, 2022, Silva, 2023, Silva and Javaroni, 2024, Zampieri et. al., 2024). To this end, we have investigated the presence of computing elements into the teaching of mathematics, based on the historical-cultural method, particularly Vygotsky's studies (2014a, 2014b, 2014c, 2014d, 2014e) on consciousness and the development of the higher order psychological functions in humans. Our research is further supported by Galperin's studies (1986), which streamline the transition from student's external to internal experiences during the teaching-learning process through the planned formation of mental actions and concepts.

It reinforces the need to understand how programming environments work and how algorithmic structures are executed, both in plugged and unplugged contexts, while ensuring that these external experiences are internalized in ways that support student's psychological functions and promote real development. We defend a transformation that goes beyond the use of technological resources in social interactions. It is a cultural transformation from the point of view of what Papert (1980) called the culture of computing, in which its instruments and signs are used as symbolic mediation in the relationship between the individual and the other.

In classroom contexts, the relationships that are established between individuals during the performance of a task are symbolically mediated by signs and instruments belonging to this culture, which has transformed their natural functions into cultural ones within the new dynamics culturally established by human work, ultimately reflected in their consciousness. As a result of this scenario, we have identified the need to incorporate the culture of computer science into teaching-learning processes, particularly in relation to the development of CT and its contribution to the formation of students' mathematical concepts.

In this article, we present an excerpt from our most recent research, which was guided by the question: *How can the process of forming mental actions foster the development of CT in students, and what is its contribution to the formation of the concept of regular polygon?* We sought answers through specific objectives, such as:

- Identifying the presence and influence of the culture of computer science in students when solving mathematical tasks organized according to Galperin's (1986) stages of the planned formation process of mental actions and concepts.
- Analysing the contribution of the development of CT to the assimilation of the concept of regular polygon by students whose attitudes are shaped by the influence of the culture of computer science.
- Propose a learning dynamic that integrates the culture of computer science with the study of geometry, promoting the development of CT and the formation of the concept of regular polygons from a historical-cultural perspective.

In this way, we were able to achieve our general objective: to investigate the possible relationships between the development of CT and the genesis of the planned formation process by stages of mental actions and concepts, in order to identify its development and contribution to the formation of the concept of regular polygons among students aged between 15 and 16 years.

Theoretical framework

In this section, we present the central ideas of the historical-cultural theory (Vigotsky, 2014) and the theory of planned stage-by-stage formation of mental actions and concepts (Galperin, 1986), as well as their relations with the development of CT from a cultural perspective.

Cultural-historical theory and the conception of the development of CT from a cultural perspective

The main objective of cultural-historical theory is to understand how culture serves as a determining factor in human development and how individuals are shaped by the relationships established between them and cultural forms of behaviour.

Cultural forms of behaviour are established by the dialectical interaction between humans and their social and cultural environment (Vygotsky, 2014e). Humans are viewed as participants in a historical process, modifying the environment through the levels of development they achieved at a given historical moment, while the environment, in turn, influences their subsequent development.

For Vygotsky (1995, p. 152), culture "does not create anything, it only modifies natural attitudes in accordance with the objectives of men". This cultural origin lies primarily in the act of internalizing language, which transforms the natural functions of human conduct into cultural functions. This transformation serves to guide human development and, consequently, their thinking – the intellectual activity defined by cognitive activity in the development process.

We employ a historical-cultural theory as the foundation for our investigations into the development of CT in mathematics education, focusing on the point at which culture becomes part of human nature. Students immersed in a computational culture "not only take something from it, not only enrich themselves with what is outside of it" (Martins and Rabatini, 2011, p. 347), but also use its terms and concepts to interact with others within this culture. This interaction, external to the internalization of language, influences the natural composition of their behaviour through culture integration. We view computer science as the result of a historical process in which human beings modified the environment in response to their needs and capabilities. Human beings influence the development of their cultural environment through an essential ontogenetic activity: work.

The action that culture exerts on the human psyche is caused by its instruments and signs. In Vygotsky (2014b), they are related to the symbolic mediation that occurs during human activity, which contributes to the development of higher psychological functions. These functions "refer to intentional mechanisms, consciously controlled actions, voluntary processes that give the individual the possibility of independence in relation to the characteristics of the present moment and space" (Rego, 1995, p. 39).

The instrument mediates the subject's action on external objects and contributes to the transformation of the object. In turn, the sign acts as a cultural instrument that regulates the psychological activity of the human being, that is, it can serve as a representation, and it is through the sign that we relate to our cultural environment. Thus, signs are the cultural instruments that mediate the internal activity of the human being within their cultural environment, enabling the control of their own actions in social relations.

Mediation is an external interference that occurs in the course of development and can lead to transformations. The other individual interacts, mediated by signs, concepts, and other elements, in the social relationship that is established, supporting the attribution of meanings to the way of life of that culture. The sign assumes this mediating role in human conduct only when it is definitively used in its instrumental function in this process. In our research, we have observed that when transforming natural functions into cultural functions, the signs belonging to the culture of computing need to be identified or considered as instruments of this process for the transition from external activity to internal activity to occur and, consequently, for development to take place.

The presence of signs originating from computing in students' dialectical interactions is an essential external condition for the development of CT in the school context. In this case, the role of the teacher in this social interaction is of utmost importance. The teacher is responsible for creating the humanizing needs and guiding the use of signs in favour of the development of higher psychological functions. Moreover, the teacher should observe whether the signs originating from the culture of computing do, in fact, act as mediating instruments in the process of student's social interaction. These actions ensure that the transformation of natural functions into cultural functions occurs, leading to the new organization of thought, the computational one.

In this relationship between humans and their environment, mediated by signs, it is not possible to dissociate language and thought, even though they have different roots. Language has an influence on the structuring of thought because, as a symbolic system, it allows human beings to transmit culture, whether through speech or another socially constructed means of communication. Therefore, for the development of CT, words (signs) with specific meanings within the culture of computing, along with their meanings, are fundamental for the psychic transformation that will occur and will guide this way of organizing thought.

This thinking is shaped by the knowledge and practices of computer science. Anchored in the framework of Brennan & Resnick (2012), the knowledge and practices are grouped into four pillars. Decomposition is the pillar characterized by the process of decomposing a problem into smaller parts that can be solved. One way to identify how many parts the problem could be decomposed into is to search for similarities in the student's previous experiences. This act is linked to the pattern recognition pillar, which is also responsible for identifying patterns in the act of solving the decomposed parts.

The algorithm pillar is related to the act of organizing the solutions of the parts in a logical and orderly manner, in order to obtain, in the end, the solution to the initial problem. It is also the moment of logical organization of thought. In a way, this and the other pillars are supported by abstraction, which is the pillar responsible for identifying the essential attributes that should, in fact, be considered when solving the problem. We argue that this pillar, in light of our theoretical assumptions, consists of two processes: analysis (the act of observing all possibilities and information) and synthesis (the act of identifying, among the possibilities and information analysed, those that are necessary to solve the problem).

In this way, we conceive of CT as:

> A strategy for organizing thought, to solve and formulate problems, which occurs based on the knowledge and practices of Computer Science, such as decomposition, pattern recognition, algorithm and abstraction, when the culture of this area of knowledge is incorporated into its social relations (Silva, 2023, p. 288).

With this understanding, we have observed that it is not enough to use computational resources to carry out external activities for CT to develop. These uses must occur in the student's interaction with others and promote the transition from external to internal activity, under the symbolic mediation that is established in this relationship and that is based on the foundations of computing.

Formation of mental actions and concepts from a historical-cultural perspective of development

Then we began to address in our investigations the process of forming students' internal psychic actions, paying attention to the functional moments of the individual's activity that contributes to the internalization process. Based on Galperin (1986), we established ways of organizing the teaching task and the pedagogical dynamics that foster the development of students' thinking and conceptual formation, considering their activity as the path through which the transition from external reality to internal reality occurs.

Talízina (1998, p. 14, our translation) defines activity as "the process of interaction between the subject and reality in problem-solving, so that from the semiotic mediation (signs, language) it results in the formation of their psyche". Activity is, therefore, the core of the development process. In this relationship, the individual interacts with their reality as a consequence of their needs and objective motives, which promote the development of their psychological functions.

For Galperin (1986), this activity should be fostered following three moments specific to the cognitive cycle: orientation, execution and control of the action. Since activity is present in the process of internalization and assimilation of actions, the planning of the latter will occur in stages: 1) materialized, which is the interpretation of that which is concrete; 2) of language, based on speech and collaborative activity, so that it can be; 3) mentally represented. Thus, mental action is the ability to mentally carry out the transformation of an object. In this sense, the appropriation of culture and the transformation of reality mediate and generate the development of the individual.

In Silva (2023), we conclude that the development of CT follows the form: material – verbal – mental. In particular, it can support the process of forming students' mathematical concepts, supporting the teacher in conducting the teaching-learning process by paying attention to how to establish the task and provide guidance to the student during their activity.

For the formation of internal action to occur in a planned and guided manner, based on actions external to the individual, Galperin (1959, 1986) presented four stages, namely: 1) formation of the Action-Guiding Basis (BOA); 2) formation of action on the material plane; 3) formation of action on the external language plane; and 4) formation of action on the mental plane.

In the process of forming mental actions and concepts, the guiding basis of action plays a fundamental role as the external responsible action for establishing and base the beginning of the development of this cognitive process. This is due to the directive nature that the study activity assumes. The BOA is thus established by the teacher in the way of organizing teaching, characterizing itself as a beneficial orientation for the student.

It is essential that the BOA is constituted by a high degree of generalization, a complete level of detail, and an independent level regarding the method of obtaining. In addition, it includes three models in its composition: the object model, the action model and the control model.

The *object model* represents the conceptual knowledge of the object/phenomenon to be assimilated, addressing the question "what is it?”. The *action model* represents the operational knowledge of the object/phenomenon to be assimilated. In other words, it is characterized by the set of operations to achieve success in the action and also makes it possible to elaborate the answer to the question "how is it done?”. The *control model* represents the criteria for regulating the process, allowing for the verification of successes and errors based on the success of the planning and execution.

It is important to understand the concept of the zone of proximal development (ZPD), as stated by Vigotsky (2014 – Volume II). This refers to the movement between an individual’s actual development and their potential development, within the dynamics established through interactions with others. Therefore, between the two points – actual and potential, which are not strictly defined – lies the individual’s capacities in the process of becoming.

These capacities call for the resolution of tasks, initially with the help of others and – as a consequence of interactions and their symbolic and instrumental mediations – later, these capacities and similar situations are involved independently. Therefore, at the other end of the ZPD, there are possible performances that can be achieved by the individual.

This distance understood between the preambles of such ends represents the field of possible development. Within it, the actions and mediations carried out through the interaction of the subject with peers (teachers, tutors, other students, etc.) are logical, with a view to enhancing the development of the student, under appropriate conditions and contexts.

The dynamics of the stages of the planned formation of mental actions depend on the transformation of real development into a close development (which will become real) and on the possibilities and experiences of the students. Therefore, an interaction with the other is present throughout the process to bring to light mediations and orientations specific to this development, which is neither static nor linear. In the background of this process, there are motivations, needs, and objectives to be achieved, which is a concern for what Leontiev (1978) presents in his theory.

Although the stages of the planned formation of mental actions have their own form of understanding and execution, they are related in such a way that students incorporate the object of knowledge presented in the task into the mental plane from the first stage. It is observed in Silva (2018), Zampieri et al. (2019), Silva (2023) and Silva and Javaroni (2024) that this process occurs when considering, for example, the development of the foundations of CT in mathematics classes.

However, there is no absolute linearity, in which first the security is developed, then the patterns are confirmed, then the process of data analysis and synthesis is carried out and, finally, it is organized in the form of a logical sequence and order of steps in order to obtain the final solution. While there is a general orientation stimulated by this organization, the process of assimilating the action is complex. One pillar may become more prominent as the other requires less dependence on the process of resolving the proposed problem, similar to what occurs in the planned formation of mental actions.

There is a need to establish an adequate BOA (Action-Guiding Basis), that is, to consider the object of knowledge involved and cultural aspects of computer science, which are advocated in the student's social environment. This need arises from the assumption that external action is responsible for establishing and substantiating the beginning of the development of this cognitive process in such a way that the presence makes sense and there is a possible contribution from the pillars of CT, during the process of forming the action on the mental plane.

Therefore, the teaching activity requires a structure that considers these cultural aspects of computing present in the student's environment so that this structure allows for reflection on the object of study, as well as contemplating their previous experiences and knowledge – which they probably need to overcome – and promoting their cognitive interest.

When considering the system of invariant operations that compose the action model and materialize it (material form of the action), we seek an establish a connection with the pillars of decomposition and pattern recognition, as means that enable the formation of the action on the material plane. This stage represents the moment when student performs tasks with external support. The two pillars can support the conscious materialization of the action, based on experiences originating from the cultural environment, which motivates them and makes sense for their development.

Regarding the internalization of the action model (verbal form of the action), we seek an approximation with the algorithm pillar, as conceived by Krutetskii (1976), as a means that enables the formation of the student's action in the external language plane and the identification of this formation by the teacher. Following the decomposition and recognition of patterns that support the resolution of the parts of the problem, the process of organizing the solutions begins in an orderly and optimized manner, guided by the meanings of the words and signs presented in the previous stage and linked to the object of knowledge.

In this act of logically sequencing the solutions, there is still the presence of pattern recognition, in a minimized form. In addition, there is the presence of external language, enhanced by its own development, allows the student to interact with their peers to establish meanings for the concepts used in their productions (results). The elaboration of these productions serves as a means for the student to communicate their ideas with their peers, as a communicative action proper to the subject rather than being based on reflections of material actions. This is the moment when the teacher is able to identify whether there is a cultural influence of computing in this development.

The pillars of decomposition and pattern recognition are minimized throughout the process. Furthermore, the constitution of the algorithm pillar highlights the existence of action in the realm of verbal thought, through reflection and communication between peers. Likewise, the abstraction pillar is constituted by the contrast between what is established in the field of external language (which moves towards the mental field) and what was seen as a model of action, focusing only on the details that are important.

The focus on essential attributes can support students in developing the execution and control of actions (mental form of the action) that are independent from their peers. Thus, we seek an approach to the abstraction pillar as a means of enabling the formation of the student's action in the mental plane. The development of this pillar can contribute to the automation of actions and the reduction of orientation, facilitating the assimilation of the learning object. Therefore, these are the relationships that we have observed in our research with students, without disregarding the complexity of the cognitive process.

In this article, we present a selection of data and their analysis from a study we conducted from 2019 to 2023, in which we carried out a teaching experiment with the aim of investigating the possible relationships between the development of CT and the genesis of the planned formation process by stages of the mental actions and concepts of students aged between 15 and 16. The teaching experiment were situated in a social and school context that is historically and culturally transformed by the presence of computer science.

We present a discussion that enunciates our understanding of how the development of students' CT occurs through the lens of cultural-historical theory. Next, we present the methodological approach, objectives and subjects of the field research, elucidating the previous discussions through the data that will be presented. Finally, we present considerations about this study and projections for further research in this area.

Methodology

In our research, we employed the historical-dialectical materialist method, which considers “the concrete and real conditions of the object of study, the historical process, the role of time, and the circumstantial and concrete conditions in this process” (Beatón, 2017, p. 22, our translation), in studying of the human psyche. This method takes into account the new formations and the main activity of the subject in the dialectical relationship of the process, which causes successive transformations in this dynamic. The choice of methodological procedures was based on the characteristics of the relationship between the internal and external aspects of the students. Therefore, we used external observation of behaviour and self-observation, both of which are common procedures in the method adopted by us.

Since the production of data for this research took place in 2021, a period in which we were conditioned by social isolation caused by COVID-19, we respected the social interaction protocols imposed by the Brazilian government. Thus, the six students participating in this study were grouped into two subgroups with three students in each. Each subgroup alternated the day of being in person at the school's physical facilities. Although they were together in person, our interaction was carried out through the Google Meet platform. The records were made through audio and video recordings and field notes.

The data from self-observation were produced through the development of teaching tasks, which led the students to reflect on key concepts/terms at the beginning and during the three meetings held, each lasting 2.5 hours. Additional data were collected through semi-structured interviews. The purpose was to obtain data that expressed immediate self-observation after completing the tasks, and self-observation after a period of reflection. The semi-structured interviews also aimed to obtain data regarding the historicity, the characteristics of the social and cultural environment of the research subjects, and the meaning they attributed to the school.

In this article, we will discuss the results of our interaction with three students who constituted one of the participating subgroups. Among them, two students were 15 years old, and one was 16 years old, all regularly enrolled at the Adélio Ferraz de Castro State School, located in the city of Vargem, in the state of São Paulo, Brazil. We will call these students Ana, Paulo and Otávio, which are fictitious names that we gave them to protect their identities. We chose to discuss data from one subgroup due to space limitations in this article.

We used Scratch and GeoGebra software. These tools were chosen so that the actions developed would be linked to the object of study – in this case, higher psychological functions – rather than the understanding and comprehension of how to use the technical tool, since they were already familiar with both software programs, despite frequently using only GeoGebra.

The tasks performed were intended to address the system of concepts related to regular polygons. The treatment and analysis of the data produced were based on the theoretical-methodological foundation presented, considering three principles presented by Vygotsky (2008): i) analysing processes rather than objects; ii) explanation versus description; and iii) the problem of fossilized behaviour.

Analysing processes rather than objects is linked to the analysis of the essence rather than the visible appearance of the development of thought or voluntary behaviour. What is apparent is related to what is essential, but they do not coincide. This leads the researcher to prioritize processes over objects during analysis.

Explanation versus description is related to the explanation of causes rather than just describing the effects. By explaining through the analysis of the process instead of explaining the object, we can identify whether the technological resource with the entire cultural symbolic system of computer science is really a social stimulus to the point of modifying the psychological instrument, in order to facilitate the development of thought or other higher psychological functions.

The problem of fossilized behaviour is linked to historicity and the identification of psychic processes that appear to be mechanical and automated. However, in the beginning, they required an active dynamic to come into existence. The archaeologist, when finding a fossil, observes it and analyses it in order to rescue the living being. The same happens with this principle.

In relation to these principles, Vygotsky (2014b) proposes that the analysis of the development of higher psychological functions should be based on an analysis that seeks "the relationships between the fragments that make up the whole, since the ways in which these fragments relate to each other both determine them and are determinants of the composite whole" (Zanella et. al., 2007, p. 28). Thus, we consider two units of analysis: the experience and the action and communication.

In the *experience* unit of analysis, the focus is on understanding the reality of students from their own perspective. The aim is to identify their awareness, regarding their school and social context, specifically: the use of machines arising from the advancement of computing; and the incorporation of cultural aspects of this area of knowledge into social actions.

In the *action and communication* unit, the focus is on the formation of the student's mental actions. We discuss the moments in which they develop teaching tasks guided by Galperin's theory (1986). We also seek to elucidate characteristics of the development of CT in the process of forming mental action, with the aim of answering the question that generated this investigation, which characterizes the achievement of its general objective.

Results

In this section, we present and discuss the application of a task with students Ana, Paulo, and Otávio. The task aimed to foster the development of the concept of regular polygons while integrating the development of CT articulated with the formation of students' mental actions.

Before we began developing the teaching tasks, they wrote down the meaning of words (signs) that we would use throughout the process of forming the mental action, such as polygon, regular polygon, angle, vertex, measure, congruent, among others linked to the field of Geometry. In addition, we proposed a teaching task in order to identify their prior knowledge regarding regular polygons.

In one of the questions of the mentioned task, they had to calculate the measure of the internal angles of a regular pentagon. Ana and Otávio considered that the sum of the internal angles was 360°. They appeared to confuse this with the sum of the internal angles of a quadrilateral or the sum of the external angles of the pentagon. In order to understand the discussion that will be held later, it is important to note that the information that the sum of the internal angles of a polygon is 360° arose in this task of obtaining prior knowledge of each of them. This situation may have been caused by the understanding that the signs were in the field of significance. Therefore, they were in the sphere of what is perceptible in the material field, instead of the sphere of meaning, that is, abstraction.

Once this situation was identified, the discussion was resumed with the students during the formation of the BOA regarding regular polygons, in an attempt to promote in them the meaning, which would make the link between meaning and significance. We began the formation of the BOA by asking them what a polygon is. This question was established when we resumed the naming of polygons in the previous teaching task with them.

Otávio considered that the polygon was the face of a polyhedron and, therefore, is one side of the geometric figure. This is not the definition of a polygon, but it was one of the ways the student used to represent his concept. There is, once again, an explicit formation of what is tangible about the concept and there is no formation of its abstract entity. To confirm that Otávio’s speech originated from this relationship, we showed the image of a Rubik’s cube and noted through the dialogue woven with it that Otávio attributed a significance to the sign vertex and edge, despite exchanging the meaning of the words vertices and segment.

However, Otávio directed the visual component to the actions performed in terms of creating three-dimensional digital prototypes, outside the school environment. When presenting the idea of a polygon as a side, he mentioned a principle that resembles the pillar of decomposition present in the cultural environment of computing. This perception appeared when referring to the division of the faces of the polyhedron, indicating that although he used colloquial language, he placed an essential clue to the concept, which is the approach of the concept as a face (flat region) of three-dimensional figures.

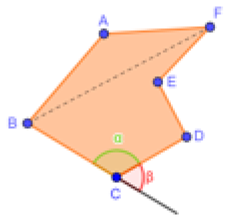
When asked about this scenario, he responded that it is practical and useful knowledge in the informal everyday environment. However, its teaching is not made possible by the school. In his speech, we observed a denunciation of a dissociation between the student’s reality and the teaching of Mathematics. The complaint was for not encompassing the actions present in his social environment. Otávio's speech exposed the distance between the school and the student's cultural environment, transformed by computer science.

We emphasize the need to consider the computational culture present in society. After all, it has culturally changed the individual in his relationships, even without high-performance instruments. It currently constitutes a mediator for the development of students at a conceptual level, since it takes into account that the formation of actions, on a mental level, begins with external experience.

With the representations of the polygons from the first question as a reference, we ask again: "what are polygons?". Otávio replaced his definition with the statement that it is a face, redirecting the question to polyhedrons. Based on the concept that the faces of every polyhedron are polygons, the students recognized that every polygon is made up of components such as edges – straight line segments that form the sides of the polygon – and vertices, that there are no curves on its sides, and that every polygon is the region/surface that leads to the concept of area.

At this point, we identify that it would be necessary to propose something necessary for the formation of the BOA (Action-Guiding Basis) to the students, regarding the ideas and concepts concerning the elements of a polygon (Figure 1), so that they could be led to develop the definition of a polygon.

ELEMENTS OF A POLYGON



- Vertex of a polygon: point of intersection between two consecutive sides. It is named with capital letters. Example: A, B, C, D, E, F and G.
- Side of a polygon: line segment that joins two consecutive vertices. Example: $\overline{AB}, \overline{BC}, \overline{CD}, \overline{DE}, \overline{EF}, \overline{FA}$..
- Consecutive vertices: these are vertices that form the ends of one side of the polygon. Example: A and B, B and C, C and D, D and E, E and F, F and A.
- Consecutive sides: these are sides of the polygon joined by the same vertex. Example: sides $\overline{DE}$ and $\overline{EF}$ are joined by vertex E.
- Perimeter: sum of the lengths of the sides of the polygon. Area: measurement of the internal region of the polygon delimited by its sides.
- Gender (n) of a polygon: number of sides of the polygon. Example: polygon with 6 sides (hexagon).
- Diagonal: line segment that joins two non-consecutive vertices. Example: BF.
- Internal angle: internal region of the polygon formed by two consecutive sides. It can be represented by letters of the Greek alphabet, by letters of the Roman alphabet in capital letters and with a circumflex accent or by indicating the three vertices linked to the two consecutive sides with a circumflex accent on the vertex that joins them. Example: α, $\hat{C}$ or $D\hat{C}B$
- External angle: external region of the polygon formed by a side and the extension of the side consecutive to it. It can be represented by letters of the alphabet. Example: β.

Figure 1. Theoretical material present in BOA

In addition to this theoretical material, there were issues to be resolved in the teaching task that constitutes the BOA (Action-Guiding Basis). For example, in question 1 (Figure 2), they had to indicate which of the polygons is regular. The concept of regular polygon for them was not yet assimilated to its greatest degree of generalization. There is a relationship of defining the concept based only on its representation. However, the identification of characteristic elements of the concept occurs, such as: the angles of the figure on the left appear to be of the same measure; the angles of the figure on the right are different.

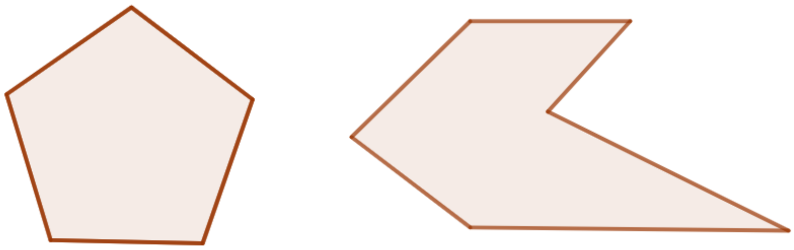


Figure 2. Image present in question 1 of the teaching task that constitutes the BOA

Otávio also defended the mistaken idea that all regular polygons have angles whose sum is 360°. He referred to the image on the left, indicating that, in it, the sum of the angles will not result in 360° because the measurements are not the same. This identification occurred because the concepts of line and segment were not assimilated to their maximum degree of generalization, given the occurrence of the exchange of terms. The scientific concept of polygon has its genesis and development, produced historically, in the point, line and segment. However, as these last three concepts were not addressed by us in the formation of BOA, the foundation was not laid. In our interactions, we assumed that the students had appropriated the concept system, which constitutes the elements of the essential relationship of the polygon concept.

By observing the meanings, he attributed to the signs we proposed in the first interaction with them, it was possible to notice that, when defining some polygons, the student used the term "geometric shape". After the discussions, we understood that, when mentioning 'geometric shape' to define a square, for example, he was referring to a polygon with sides of the same length. In order to understand a psychological phenomenon, it is important to establish this initial action of highlighting the meanings of the signs for the students, which will be used in solving the task.

It is worth remembering that the idea that the sum of the internal angles is equal to 360° in all regular polygons emerged in the task of surveying prior knowledge, indicating it was something ingrained. In an attempt to minimize this conceptual error before it became fossilized, we modified the teaching tasks adopted. We emphasize the importance of carrying out this pedagogical dynamic that we are reporting and discussing, which allows the establishment of tasks based on what is being evidenced, in order to reach the phenomenon investigated in its entirety.

Paulo, in turn, considered the symmetry in the image to justify the reason why the image on the left of Figure 2 is a regular polygon while the image on the right is irregular. The student provided an example by mentioning an isosceles trapezoid, explaining that when drawing a vertical axis of reflection symmetry, the figure will be divided into two symmetrical parts, which he deemed a necessary condition for a regular polygon. Since they were unable to contradict their colleague, Otávio and Ana added symmetry as a condition for the definition of a regular polygon.

From that moment on, we began a period of observation of Figure 2 with the aim of understanding what concave and convex polygons are. In this observation, we developed the idea of the 'algorithm pillar' with them, beginning a process of appropriation, if it made sense to them, in the cultural environment in which they were immersed. We followed the structure of a logical and ordered sequence of steps so that they could organize the characteristics that they would observe, with the adoption of the conditions "if", "then" and "else", used in computer science. For example, if the polygon has at least one angle greater than 180°, then it is concave. If not, it is convex. Likewise, if when joining a vertex to another non-consecutive vertex of the same polygon, all the line segments formed remain included in the internal region of the polygon or in its contour, then it is convex. If not, it is concave.

The algorithm pillar was approached in order to support them in communication among their peers, with the adoption of specific terms related to the object of knowledge. In addition, we supported them in organizing their thoughts and speech during their interactions. Following this, we developed a teaching task in which we asked students to classify six polygons as regular or irregular, based on the definition formulated by them. This served as the control model in the formation of the BOA on regular polygons.

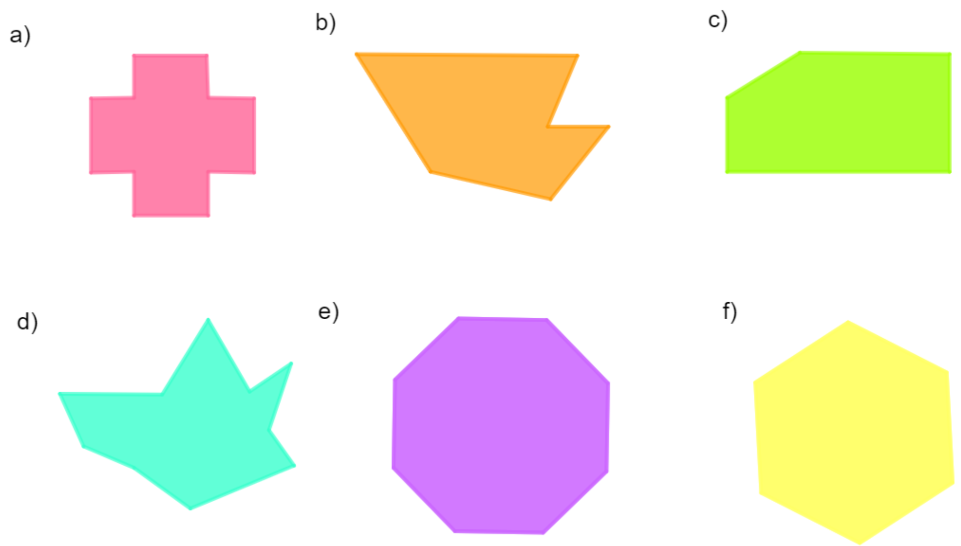


Figure 3. Polygons of the control model in the BOA formation

After the students had formed the BOA, we began the stage of forming the action on the material, external language and mental planes. We introduced the GeoGebra software to the students and explained how to use the polygon and regular polygon tools. We also introduced the Scratch software and explained how to use the blocks to build the algorithm. We then began several interactions with them, using these instruments and the signs of mathematics and computer science with the aim of creating contradictions in their definitions of regular polygons, so that they could develop their activities that would lead from the experience of forming the action on the material plane to the mental formation of the concept.

For example, they built a rectangle with the polygon tool and a pentagon with the regular polygon tool, as can be seen in Figure 4.

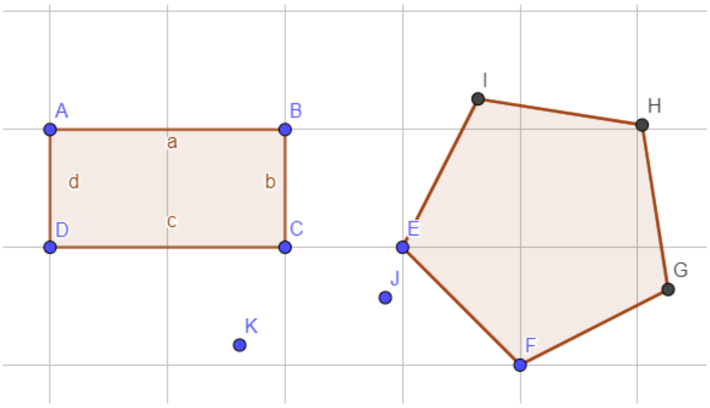


Figure 4. Rectangle and pentagon built in GeoGebra

When observing the images, Otávio questioned whether the pentagon constructed using the regular polygon tool would have sides of equal length. In order to investigate this situation, we used the tool called "length, distance and perimeter" to measure the sides. Upon founding that all the sides of the polygon were of equal length, Paulo stated that, in addition to this characteristic, the figure was also symmetrical.

Although Paulo was the only one to consider symmetry as necessary to classify a polygon as regular, the validation done with the pentagon did not confront Otávio and Ana's definition, since the image formed was symmetrical and had congruent sides. However, we asked them to analyse whether the rectangle would be a regular polygon or not, as a way of confronting them regarding their definitions.

Paulo drew the line segment BD, one of the diagonals of rectangle ABCD, as can be seen in Figure 5. Based on it, we started a dialogue, which was considered essential for the formation of action on the material plane. We observed that they used the pillar 'pattern recognition' as a strategy for organizing thought to defend their definition of a regular polygon.

In his speech, Paulo brought up that everything in everyday life follows patterns and their union generates other day-by-day forms and actions. Therefore, for the student, if every regular polygon is constructed by an algorithm – which unites the patterns identified by them in the definition of a regular polygon and there is a variable that is the number of vertices – then, whenever this variable is 4, all the figures will be the same in shape, what can be changed is the size of the line segment.

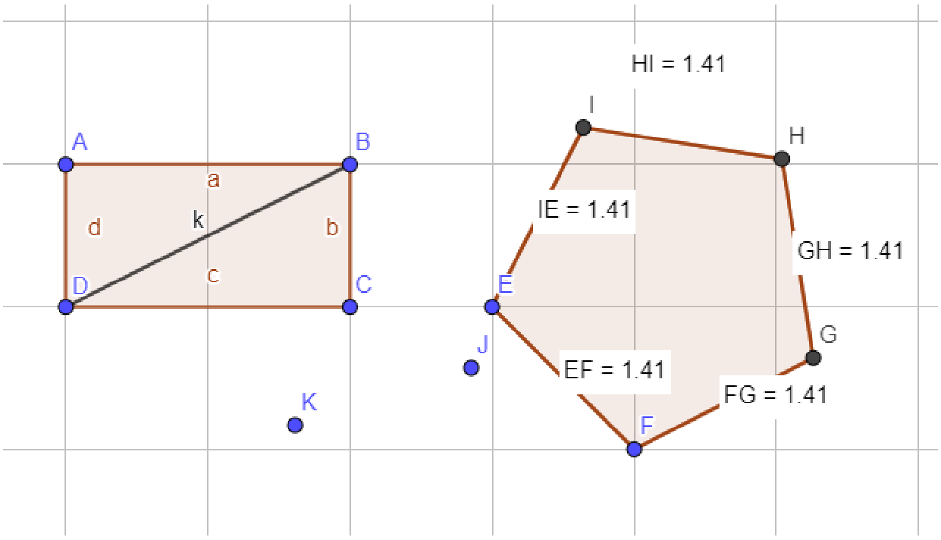


Figure 5. Rectangle with one of its diagonals and regular pentagon with the measurement of its sides

Paulo's speech was appropriate for us to ask about the rectangle constructed previously, named as regular. For him, the regular polygon tool is programmed to make only squares, instead of building all other types of regular 4-sided polygons. It is clear that, for Paulo, the presence of symmetry constitutes an element of the concept of a regular polygon.

In order to verify whether this definition would hold up with other examples, we used the Scratch software to build the representation of regular polygons. This was an opportunity to form an action in the field of external language, based on the algorithm pillar. These guidelines were important, mediated by a known polygon, which was the subject of previous discussions. Figure 6 translates the representation they built.

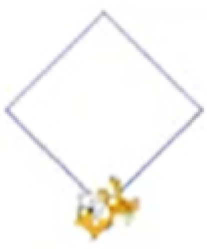


Figure 6. Representation of a square in Scratch made by Ana, Paulo and Otávio

This construction took place in such a way that they broke down the definition into two characteristics: angles and sides, which were the same ones previously listed by Ana. For each characteristic, they recognized the patterns present in the definition, namely: the sides having the same measurement and the sum of the internal angles being 360°, which determines that each internal angle will be 90°.

With the realization that it would be necessary to repeat the same sequence of commands four times to build a side and an angle, they set up the algorithm of a pattern with the blocks: move and rotate. Then, they used the control block to repeat the necessary four times. This was the first time they used the Scratch software, but they recognized the similarity of its language to that of games and software used outside the school environment. In addition, Ana clarified that adopting patterns in her daily actions is part of her.

We asked them to explain the productions up to that point with their respective justifications. This action was important to verify whether the organization of the blocks included a logical and ordered sequence, which is a characteristic of the Scratch software. It supported the stage in which the students' action was being formed, and it also allowed us to identify the development of the pillars of decomposition and pattern recognition through their statements.

In addition, we should look at the contribution of the algorithm pillar in the stage of action formation in the external language plan. The justification for this focus lies in the students' attitude. This is because, instead of schematizing the logical and ordered organization of the information with definitions, they resorted to signs. In other words, they relied on words, whose meanings constitute the concepts addressed, such as: right angle, congruent sides, congruent angles, among others.

The use of signs and vocabulary, related to the object of knowledge, is essential for the stage of action formation in the external language plan. However, at this point, it was not yet guaranteed that they were fully in this stage of action formation. However, since we knew where we were supposed to go, we tried to stimulate this development by starting the teaching task of constructing the representation of an equilateral triangle in the Scratch software.

At this point, organizing the construction process in Scratch, in a logical and ordered sequence, supported communication between them. This is a level of understanding in which, in their interactions, they use signs linked to the object of knowledge. In addition to the algorithm created in the Scratch software, the three students structured their ideas sequentially on a sheet of paper. This further demonstrated how the algorithm pillar can support the moment of formation of action in the external language plane, since it is established in the field of verbal thought.

Paulo's insistence on symmetry as part of the definition of a regular polygon led us to try to identify the origin of this perception. We found that it originated from the examples covered in his math classes, which only examples of reflection symmetry were used. Here, the importance of this dialectical movement, present in the interactions between the researcher and the research subjects, guided by contradictions, becomes evident.

If we had the intention of considering the data superficially, as they are produced at first glance, at the end of the meeting, we would have concluded that everyone considered that the polygon is regular if it is possible to establish two other smaller and symmetrical polygons on its surface. This highlights, once again, the importance of the double-stimulation method in research on the cognitive development of the individual, because it considers what is rooted in the individual's cognitive structure.

Paulo's incisive statement about symmetry provoked us to reflect on the conditions necessary to promote the development of the scientific concept of regular polygons. In this case, the concern would be to cause contradictions to Paulo's statements, which would put him in a thought movement to seek arguments that would consolidate or overcome his conception. At the same time, these contradictions would promote an awareness of such characteristics of the object of knowledge. Also, it would understand the perception of the origin of the idea that polygons are regular only if two other symmetrical figures can be obtained from it, with different measurements.

Thus, we developed a teaching task with the aim of promoting reflection on the concepts of similarity and symmetry. By observing the pairs of polygons in Figure 7, we began a dialogue about similar polygons and regular polygons. The aim was to recognize patterns in order to decompose them based on their characteristics.

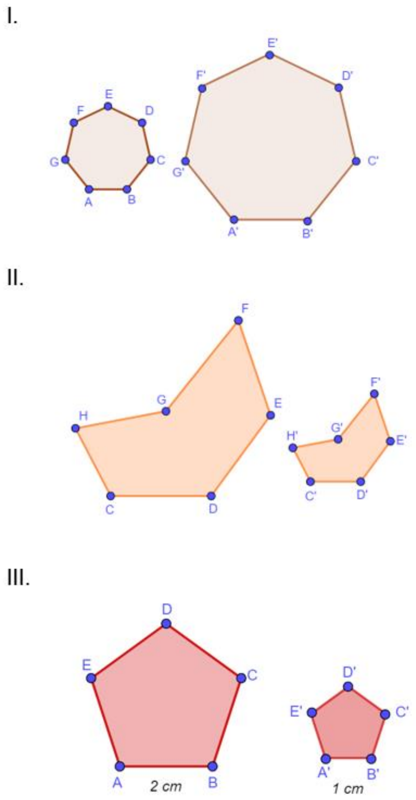


Figure 7. Polygons from the teaching activity on similarity and symmetry

When recognizing patterns based on the characteristics under which they decomposed the polygons, items I) and III) aligned with Paulo's statement, which was validated by Ana and Otávio. However, item II) caused a contradiction, as they were unable to divide the polygons into two symmetrical parts. Therefore, according to their definition, it would not be a regular polygon and it could not be similar either.

This is a contradiction of the definition presented by them, since the polygons CDEFGH and C'D'E'F'G'H' are similar. From this action, they made several conjectures, two of which stand out: a polygon does not need to be divided into two symmetrical polygons to be regular; and that every regular polygon is symmetrical, since for them these two quadrilaterals are not regular.

Regarding the first conjecture, we developed a teaching task with them in order to reduce the dependence on the representation of the action in the material field and increase the formation of the action in the field of external language. They constructed the representation of a regular hexagon in the Scratch software, with an angular movement of 60°.

When constructing this regular polygon, they reinforced the initial proposition that the sum of the internal angles of a regular polygon is 360°. They adopted the algorithm pillar as a reference to organize their thoughts and for communication between them. However, they observed that the sum of the internal angles of a regular hexagon is 720°, given that all the angles are congruent and each internal angle measures 120°.

Unlike the other moments, they did not need to obtain the measurement of all the internal angles to quickly conclude that they would all be 120°, which results in a sum of 720°. As a result, we assume that they understood, in a deeper way, the meaning of congruent angles and internalized it as one of the characteristics of regular polygons. Therefore, there is an indication of a move towards the formation of action in the field of external language, provided by the decomposition of the polygon, according to its characteristics, and the recognition of patterns.

This process of becoming aware of the object is important for the non-linear transition from the formation of action in the material field to the field of external language. It is a moment in which language and thought connect, allowing the student to become aware of their actions, which are mediated by intellectual operations and produced through external experience and the generalization of the words.

The importance of developing the various teaching tasks that induce contradictions and reflections among students lies in the fact that these tasks, along with interactions with peers, enable actions in the material plane to provide the conditions for reaching the mental plane. This higher psychic function begins to regulate the students' activities, allowing them to communicate their ideas with their peers and reach appropriate meanings. This higher psychic function enables the meanings to move between different tasks as a communicative action proper to the subject rather than being solely based on reflections of material actions (Talízina, 2001; Galperin, 2001).

In the transition from material actions to actions in the external language plane, the students realized that they needed to change their last definition of the concept of regular polygon, as they questioned whether there was any relationship between the equilateral triangle and the regular hexagon. It was then that we began to pay more specific attention to providing the conditions for the development of the abstraction pillar. With this, they would identify the essential attributes through the process of analysis and synthesis, and would use them in the process of moving from the external language plane to the mental plane.

Ana recalled that every polygon can be divided into triangles and quadrilaterals. So, she proceeded, through pattern recognition, to draw four straight lines on the regular hexagon (Figure 8). Paulo recognized that it was possible to place a circumference circumscribed to the hexagon and so he did, asking: "How is it possible for a 360° circumference to circumscribe a polygon whose internal angles add up to 720°?".

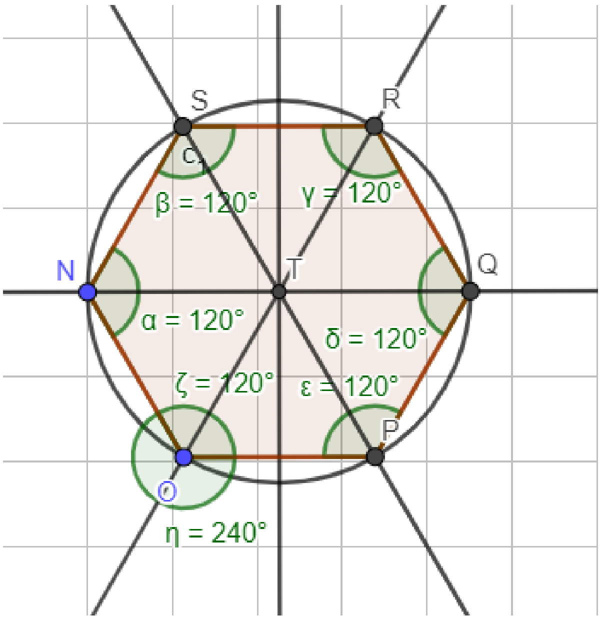


Figure 8. Representation of a regular hexagon inscribed in a circumference in GeoGebra software

Otávio's questioning and encouragement were timely for the trio of students to consider this relationship, which exists with the degree 360° in the definition of a regular polygon. In other words: it is not the sum of the internal angles that results in 360°, but the sum of each external angle with its respective internal angle. With the identification of this attribute, they conjectured that they would probably find other exceptions besides the equilateral triangle and the regular hexagon. In this way, the abstraction pillar (analysis and synthesis process) was incorporated into the process, which allowed reflection on the definition they began to consider: every regular polygon is symmetrical and has the sum of the external angles equal to 360°.

To promote further discussion, we propose a teaching task with the objective of constructing the representation of a regular pentagon in the GeoGebra software. Upon completing the task, they realized that each internal angle measured 108°. Therefore, they validated that the sum of the internal angles of a regular polygon is not 360° and that this is the measurement of the sum of an external angle with the respective internal angle.

Then, they built the algorithm, in the Scratch software, in an optimized way. And, without any doubt, they concluded that the angle of rotation would be 72°, as it would be the measurement of the external angle. Here, it is possible to see that the abstraction pillar begins to provide intellectual autonomy for them. This reinforces the development of the abstraction pillar as a means of enabling the formation of the student's action on the mental plane. By identifying the essential attributes, regarding the external and internal angle, they gained more confidence in solving what was proposed to them.

They continued their investigations by constructing a circumference circumscribed to the pentagon and, with the contrast of having a 360° object circumscribed to a polygon with the sum of the internal angles equal to 720°, they began to identify, through pattern recognition, that something was wrong. Based on this observation, they related it to the way they obtained the external angle to rotate the sprite in Scratch and obtain the representation of the hexagon, which was by dividing 360° by the number of sides of the regular polygon.

It is worth mentioning that the students themselves mentioned the support of the algorithm pillar so that they could observe and remember how these values were obtained, in the previous examples. They concluded, therefore, that in the Scratch software they do not consider the sum of the internal angles equal to 360°, but rather the central angle of the polygon, which will always have this measurement, as it represents the complete turn of a circumference.

This reflection, occurring during the interaction between them and mediated by their speeches, characterizes the moment when the external experience gains mental representations. It is a unique moment, regulated by language, in which the action becomes part of each student's thoughts, allowing them to execute and control the action independently in relation to their peers (Galpern, 1986). We are on the path to the transition between the formation of the action in the external language plane and the mental plane.

Since this is an individual moment, each student in this trio presented their definition regarding the concept of regular polygon, in the excerpts.

Paulo:	A regular polygon must be symmetrical, it must have edges, vertices and the sum of its central angle must be 360°.
Otávio:	A regular polygon is a polygon that must be symmetrical, the sides have the same measurement and its central angle must be 360°.

Ana: A regular polygon has sides of the same measurement and the angles also have the same measurement, with the central angle being 360°.

This movement by Paul of advancing and resuming previously seen concepts is important for his own awareness of the object of knowledge. It also ensures that the formation of mental action occurs, moving beyond the field of superficiality, that is, without creating the necessary conditions for the concept to promote the formation of thought.

Furthermore, with a view to forming the action on the mental plane, we carried out a teaching task in which there are representations of irregular polygons associated with the number of sides of some polygons. The presentation and discussion of this image constituted another strategy to promote the development of necessary principles of the teaching activity: the execution and control of the action, which are important for the formation of the mental action and the concept (Galperin, 1986).

We approached them with the proposition that they argue why the polygons in the task are not regular. Based on their speeches, we observed that these are manifestations of the formation of the action on the mental plane. In other words, this reflects the objectification of what Galperin (1986, 1992, 2001) advocated about this stage: the three students appropriated, on a mental level, the theoretical orientation that directed the work carried out with the BOA. The argument – for the affirmation of the occurrence of such appropriation – is the process itself, experienced with them, guided at all times by the BOA. It can also be observed by the guiding role that the mental action assumed in the execution of the last task, that is, of an objective action.

The generation of stimuli and contradictions – necessary for promoting this development as a consequence of the various iterations during this process of formation of the action – moved from the material plane and developed to the mental plane. It was they who gradually led – by means of tasks with guiding content – the interaction with the other and the adoption of the strategy of organizing thought based on the foundations of the culture of computing. As a result, the concept of regular polygon constitutes a means for the formation of other scientific concepts, since, through the previous dialogue, it is possible to observe its characterization as an image or representation of the concept.

Final considerations

In this article, we discuss the development of CT through the lens of the Cultural-Historical theory, considering that it is “a strategy for organizing thought, to solve and formulate problems, which occurs based on the knowledge and practices of computer science, [...], when the culture of this area of knowledge is incorporated into its social relations” (Silva, 2023, p. 288).

Like Vygotsky, we attribute great importance to the social aspect, which, historically impregnated by culture, transforms the individual’s natural functions to cultural functions.

These cultural functions are the psychological mechanisms acquired in the relationship with the other that guide the ways of acting in this social and cultural environment. This relationship will be guided by the mediating role of culture present in the interaction of the individual with the other, which will use language and signs to communicate and guide the individual in the production of shared meanings that, over time, regulate their psychic development.

To elucidate this perspective, we discuss a section of data from a study we conducted from 2019 to 2023 with Brazilian students aged 15 and 16, with the aim of investigating how the development of CT contributes to the planned, stage-by-stage formation of mental actions and the concept of regular polygon in these students, based on a pedagogical dynamic mediated by us. These results were produced through the historical-dialectical method, which considers the dialectical relationship between man and nature through mediation in the interaction process, which allows the observation of the concept formation process, experimentally induced, through the double-stimulation method.

From the perspective we adopted in our research, the use of words – linked to computational environments – is important to constitute signs that guide and control the individual's directed activity in the process of solving any tasks, therefore developing CT from a cultural perspective. This conclusion was obtained by identifying the presence and influence of the computer science culture in three students during the resolution of Mathematics tasks that were organized considering the stages of the training process planned by stages of mental actions and concepts.

By analysing the contribution of the development of CT in the assimilation of the regular polygon concept by students whose attitudes are shaped by the influence of the computer science culture, we observe that this contribution occurs from the relationship of the pillars of CT with the stages of the formation of mental actions and the regular polygon concept. Therefore, the pillars of CT do not occur in an isolated and linear manner; instead, abstraction connects them all in a process that aims to identify attributes capable of analysing and synthesizing the objects or data within the set being considered. Therefore, developing the abstraction pillar is a means for enabling the formation of the student's action on the mental plane.

But for this to happen, the fundamentals of computing, as well as the cultural aspects of computer science that are advocated in the student's social environment, need to be stimulated during the formation of BOA, as well as the object of knowledge. This action may contribute to the full appropriation of this culture and the intertwining of higher psychological functions – thought and language – in the development of CT. Guided by cultural functions, this process will contribute to the formation of the mathematical concept, specifically the concept of a regular polygon in this study.

Regarding the formation of the regular polygon concept and other mathematical concepts not presented in this article, the suggestions that our investigations have indicated between the development of CT in a cultural perspective and the planned formation by stages of mental actions and concepts are:

- The stage of action formation in the material plane is approached with the pillars of decomposition and pattern recognition as means that enable the materialization of the action model;
- The stage of action formation in the external language plane is approached with the pillar of algorithm as a possibility of internalizing the action model, through the organization of solutions in an orderly, optimized way and guided by the meanings of the words and signs present in the previous stage, as well as through the identification of the occurrence of the development of the student's CT;
- The stage of action formation in the mental plane is approached with the pillar of abstraction as a means that enables the development of the execution and control of the action, after the identification of the essential attributes of the object through the combined process of analysing and synthesizing.

These are the relationships that we dedicate ourselves to discussing and presenting in this article, considering the complexity of the cognitive process, treating the formation of mental actions and concepts in a non-linear way and influenced by the development of CT from a historical-cultural perspective.

References

Avila, C., Cavalheiro, S., Bordini, A., Marques, M., Cardoso, M., & Feijó, G. (2017). Metodologias de avaliação do pensamento computacional: uma revisão sistemática. *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação – SBIE 2017)*, *28*(1), 113–122. https://doi.org/10.5753/cbie.sbie.2017.113

Barcelos, T., Muñoz, R., Acevedo, R. V., & Silveira, I. F. (2015). Relações entre o pensamento computacional e a matemática: uma revisão sistemática da literatura. *Anais dos Workshops do Congresso Brasileiro de Informática na Educação*, *4*(1), 1369–1378. https://doi.org/10.5753/cbie.wcbie.2015.1369

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. *Learning & Leading with Technology*, *38*(6), 20–23.

Beatón, G. A. (2017). La visión integral o de totalidad en el método dialéctico, su presencia en lo histórico cultural y sus proyecciones en la práctica educativa. In S. G. L. Mendonça, L. A. A. Penitente, & S. Miller (Orgs.). *A questão do método e a teoria históricocultural: bases teóricas e implicações pedagógicas* (pp. 19–38). Cultura Acadêmica.

Brackmann, C. P. (2017). *Desenvolvimento do pensamento computacional através de atividades desplugadas na educação básica*. [Doctoral Dissertation, Universidade Federal do Rio Grande do Sul]. http://hdl.handle.net/10183/172208

Brackmann, C. P., Barone, D. A. C., Casali, A., & González, M. (2020). Panorama global da adoção do pensamento computacional. In A. Raabe, A. F. Zorzo, & P. Blikstein. *Computação na educação básica: fundamentos e experiências* (pp. 31–48). Penso.

Brazil (2017). *Base Nacional Comum Curricular*. http://basenacionalcomum.mec.gov.br/

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *Proceedings of the 2012 Annual Meeting of the American Educational Research Association*, (Vol. 1). Vancouver. http://scratched.gse.harvard.edu/ct/files/AERA2012.pdf

DiSessa, A. A. (2018). Computational literacy and "the big picture" concerning computers in mathematics education. *Mathematical Thinking and Learning*, *20*(1), 3–31. https://doi.org/10.1080/10986065.2018.1403544

Gadanidis, G., Javaroni, S. L., Santos, S. C. D., & Silva, E. C. D. (2022). Computing in mathematics education: Past, present, and future. In M. Danesi (Ed.), *Handbook of Cognitive Mathematics* (pp. 805–842). Springer. https://doi.org/10.1007/978-3-030-44982-7_35-1

Galperin, P. Y. (1959). Tipos de orientación y tipos de formación de las acciones y los conceptos. In L. Q. Rojas, & Y. Solovieva (Eds.), *Las funciones psicológicas en el desarrollo del niño* (pp. p. 76–79.). Trillas.

Galperin, P. Y. (1986). Sobre el método de formación por etapas de las acciones intelectuales. In I. Iliasov & V. Liaudis (Eds.), *Antología de la Psicología Pedagógica y de las Edades* (pp. 114–118). Editorial Pueblo y Educación.

Galperin, P. Y. (1992). Stage-by-stage formation as a method of psychological investigation. *Journal of Russian & East European Psychology*, *30*(4), 60–80.

Galperin, P. Y. (2001). Sobre la formación de las imágenes sensoriales y de los conceptos. In L. Quintanar (Org.), *La formación de las funciones psicológicas superiores durante el desarrollo del niño* (pp. 64–75). Universidad Autónoma de Tlaxcala, Departamento de Educación Especializada, México.

Javaroni, S. L., & Silva, E. C. D. (2019). Pensamento computacional nos anos finais do ensino fundamental. In M. A. Rossi & E. Serrano (Orgs.), *Educação e Sociedade* (pp. 147–167). Editora Canal 6.

Kalelioğlu, F., Gülbahar, Y., & Kukul, V. (2016). A framework for computational thinking based on a systematic research review. *Baltic Journal of Modern Computing*, *4*(3), 583–596.

Krutetskii, V. A. (1976). *The psychology of mathematics abilities in schoolchildren*. Chicago Press.

Leontiev, A. (1978). *O desenvolvimento do psiquismo*. Livros Horizonte.

Martins, L. M., & Rabatini, V. G. (2011). A concepção de cultura em Vygotsky: contribuições para a educação escolar. *Revista Psicologia Política*, *11*(22), 345–358.

Masiulionytė-Dagienė, V., Jevsikova, T. (2022). Assessing computational thinking: The relation of different assessment instruments and learning tools. In A. Bollin, & G. Futschek (Eds.), *Informatics in schools. A step beyond digital education. ISSEP 2022*. (Lecture Notes in Computer Science, vol. 13488, pp. 66–77). Springer. https://doi.org/10.1007/978-3-031-15851-3_6

Papert, S. (1980). *Mindstorms: children, computers and powerful ideas*. Basic Books.

Rego, T. C. (1995). *Vygotsky: uma perspectiva histórico-cultural da educação.* (2.ª ed). Vozes.

Sanford, J. F., & Naidu, J. T. (2016). Computational thinking concepts for grade school. *Contemporary Issues in Education Research*, *9*(1), 23–32.

Santos, C. G. (2019). *Estratégias para implantação e avaliação de um método educacional desplugado com histórias em quadrinhos para o ensino e aprendizagem associados ao desenvolvimento do pensamento computacional com alunos do ensino fundamental.* [Master's Dissertation, Universidade Federal de Sergipe]. http://ri.ufs.br/jspui/handle/riufs/11283

Santos, P. S., Araujo, L. G. J., & Bittencourt, R. A. (2019). *Um mapeamento sistemático abrangente de pensamento computacional e programação na educação básica brasileira.* [Unpublished manuscript]. https://www.researchgate.net/publication/335950756_Um_Mapeamento_Sistematico_Abrangente_de_Pensamento_Computacional_e_Programacao_na_Educacao_Basica_Brasileira

Sassi, S. B., Maciel, C., & Pereira, V. C. (2021). Revisão sistemática de estudos sobre computação desplugada na educação básica e superior de 2014 a 2020: Tendências no campo. *Revista Contexto & Educação*, *36*(114), 10–30. https://doi.org/10.21527/2179-1309.2021.114.10-30

Setzer, V. W. (2006, Abril). *Um antídoto contra o pensamento computacional*. https://www.ime.usp.br/~vwsetzer/antidoto.html

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

Silva, E. C. (2018). *Pensamento computacional e a formação de conceitos matemáticos nos anos finais do ensino fundamental: uma possibilidade com kits de robótica.* [Master's Dissertation, Universidade Estadual Paulista (Unesp)]. http://hdl.handle.net/11449/180525

Silva, E. C. (2023). *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*. [Doctoral Dissertation, Universidade Estadual Paulista (Unesp)]. http://hdl.handle.net/11449/250506

Silva, E. C., & Javaroni, S. L. (2022). A formação de conceitos matemáticos e robótica: Uma possibilidade de ensino. *Revista de Ensino de Ciências e Matemática*, *13*(1), 1–24. https://doi.org/10.26843/rencima.v13n1a15

Silva, E. C., & Javaroni, S. L. (Orgs.). (2024). *Pensamento computacional: pesquisas, práticas e concepções*. Editora UFPR.

Silva, E. C. D., Zampieri, M. T., & Javaroni, S. L. (2019). Pensamento computacional e programação: impactos na formação de professores e contribuições para práticas pedagógicas interdisciplinares. In A. Martins & A. Eloy (Orgs.), *Educação integral por meio do pensamento computacional: Letramento em programação* (pp. 206–231). Editora Appris. https://institutoayrtonsenna.org.br/app/uploads/2022/11/instituto-ayrton-senna-educacao-integral-por-meio-do-pensamento-computacional.pdf

Talízina, N. F. (1998). *Psicología pedagógica*. Ed. Academia.

Valente, J. A. (2016). Integração do pensamento computacional no currículo da educação básica: diferentes estratégias usadas e questões de formação de professores e avaliação do aluno. *Revista E-curriculum*, *14*(3), 864–897. https://revistas.pucsp.br/index.php/curriculum/article/view/29051/20655

Valente, J. A. (2019). Pensamento computacional, letramento computacional ou competência digital? Novos desafios da educação. *Revista Educação e Cultura Contemporânea*, *16*(43), 147–168. https://mestradoedoutoradoestacio.periodicoscientificos.com.br/index.php/reeduc/article/view/5852

Vygotsky, L. S. (2008). *A formação social da mente: o desenvolvimento dos processos psicológicos superiores*. (7.ª ed.). Martins Fontes.

Vygotsky, L. S. (2014a). *Obras Escogidas – I.* (Spanish Edition). Machado Nuevo Aprendizaje.

Vygotsky, L. S. (2014b). *Obras Escogidas – II.* (Spanish Edition). Machado Nuevo Aprendizaje.

Vygotsky, L. S. (2014c). *Obras Escogidas – III.* (Spanish Edition). Machado Nuevo Aprendizaje.

Vygotsky, L. S. (2014d). *Obras Escogidas – IV.* (Spanish Edition). Machado Nuevo Aprendizaje.

Vygotsky, L. S. (2014e). *Obras Escogidas – VI.* (Spanish Edition). Machado Nuevo Aprendizaje.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35. https://doi.org/10.1145/1118178.1118215

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 366(1881), 3717–3725. https://doi.org/10.1098/rsta.2008.0118

Wing, J. M. (2014, January 10). Computational thinking benefits society. *Social Issues in Computing blog*. http://socialissues.cs.toronto.edu/index.html%3Fp=279.html

Wing, J. (2016). Pensamento computacional – Um conjunto de atitudes e habilidades que todos, não só cientistas da computação, ficaram ansiosos para aprender e usar. *Revista Brasileira de Ensino de Ciência e Tecnologia*, *9*(2). http://dx.doi.org/10.3895/rbect.v9n2.4711

Zampieri, M. T., Santos, L., Silva, E. C., Souza, P. H. G., & Javaroni, S. L. (2019). Formação em serviço de professores: um olhar para o desenvolvimento do pensamento computacional em projetos interdisciplinares. In E. C. Silva & S. L. Javaroni (Orgs.), *Pensamento computacional: pesquisas, práticas e concepções* (pp. 79–102). Editora UFPR.

Zanella, A. V., Reis, A. C. D., Titon, A. P., Urnau, L. C., & Dassoler, T. R. (2007). Questões de método em textos de Vygotski: contribuições à pesquisa em psicologia. *Psicologia & Sociedade*, *19*, 25–33. https://doi.org/10.1590/S0102-71822007000200004