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Creative thinking in the didactic practice of teachers who teach mathematics

Pensamento criativo na prática didática de professores que ensinam matemática

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Abstract

This article presents the results of doctoral research whose approach is qualitative, with six teachers who teach mathematics in primary education in Curitiba and the metropolitan region as participants. The objective of this text is to present, from the participants' voices, "creativity" as one of the subsidies arising from the didactic practice with an approach in geometry through the modeling method. The theoretical support is in Morin (2005; 2011; 2012; 2019), Moraes (2015; 2019), Brandt (2016), Suanno (2016), Torre (2005; 2008), Góes (2021) and Guérios et al. (2022). Creative thinking is evidenced as one of the elements of complex thinking, present in the essence of the teacher who teaches mathematics and, in addition, "Being creative" is presented as an emerging construct of the relationships and intertwining of the subsidies "creativity" and "creating and recreate" essential and constitutive part of a complex formation.

Keywords: Creativity; Teaching practice; Complex thinking; Complexity; Modeling.

Resumo

Este artigo apresenta resultados de pesquisa de doutorado cuja abordagem é qualitativa, tendo como participantes seis professores que ensinam matemática da educação básica de Curitiba e região metropolitana. O objetivo é apresentar, a partir das vozes dos participantes, a "criatividade" como um dos subsídios oriundos da prática didática com abordagem em geometria por meio do método da modelização. O amparo teórico está em Morin; Moraes; Brandt; Suanno; DE La Torre; Góes; e Guérios et al. Evidencia-se o pensamento criativo como um dos elementos do pensamento complexo, presente na essência do professor que ensina matemática e, além disso, apresenta-se o "Ser criativo" como constructo emergente das relações e dos entrelaces dos subsídios "criatividade" e "criar e recriar", essencial e parte constitutiva para uma formação complexa.

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Palavras-chave: Criatividade; Prática docente; Pensamento Complexo; Complexidade; Modelização.

Introduction

This article presents the results of the doctoral thesis entitled *Approximations between complex thinking and didactic processes: weavings through the voices of teachers who teach mathematics*, which aimed to offer subsidies for the development of constructs for the training of mathematics teachers based on complexity to develop complex thinking and identify how it can be present in the didactic practice of these teachers. One of the constructs emerging from the results of the thesis is "Being creative," which comes from the relationships and weaves established from the subsidies "creativity" and "creating and recreating," present in the voices of the research participants, which portray teaching actions in the classroom with a mathematical approach, especially in the study of geometry.

The mapping of research involving creativity in Mathematics Education, carried out by Silva et al. (2022) in national journals with *Qualis* Capes A1, A2, and B1 in the area of teaching, with an extract from the 2013-2016 quadrennium, points to the importance of research in this area aimed at Primary II and Secondary Education. In this way, this text aims to contribute to the academic world and society by analyzing the voices of some of the participants in this research, which emerged, instigated by questions that sparked conversations about manipulable materials, the use of new technologies and how these resources can help in the teaching of geometry.

Based on the theoretical framework of complex thinking advocated by Edgar Morin, didactic practice with a geometry approach, and the school environment, the participants' voices were analyzed, highlighting emerging creativity. In this way, we bring into the discussion the creativity and creative thinking present in the practice of teachers who teach mathematics because it is one of the inputs for elaborating important constructs for teacher training in mathematics in the light of complexity. Moreover, for us, the subsidies presented are understood from a hologrammatic principle, in which "not only the part is in the whole, but the whole is in the part" (Morin, 2005, p. 205), from their relationship with the research participants and with didactic practice in mathematics.

Morin develops complex thinking based on the complexity theory, considered a new scientific paradigm whose guiding principle is non-linearity. According to Morin (2019), "complex thinking tries to account for what the mutilating type of thinking undoes, excluding what I call simplifiers, and so it fights not against incompleteness, but against mutilation" (p. 176). Complex thinking aims to relate the most diverse areas of knowledge and life, seeking to link, contextualize, and articulate them in a web where everything is entangled (Morin, 2012). This way of thinking can be understood as a recursive process, of constant comings and goings between certainty and uncertainty, between the general and the elementary, i.e., "it is not a question of abandoning the principles of classical science, but of integrating them more broadly and richly" (Morin, 2011, p. 62), of connecting the concrete parts to their

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totality.

According to Morin (2005), complex thinking

> separates (distinguishes or disjoins); unites (associates, identifies); hierarchizes (the main, the secondary) and centralizes (according to a core of crucial notions). These operations, which use logic, are, in fact, commanded by *supra logical* principles of thought organization or paradigms, hidden principles that govern our view of things and the world without our being aware of it (p. 10).

Complex thinking seeks to reconcile the different areas of knowledge and contemporary life, seeking to relate, articulate and contextualize what is distinct and fragmented and differentiate what is inseparable (Morin, 2012). In this context, by encouraging people in general to express their interests and ideas, we provide an environment conducive to creativity since freedom, as Brandt (2016) emphasizes, is an essential element for discussions to flourish and freedom of thought to be established, allowing us to be active agents in building more comprehensive and innovative solutions to contemporary problems of different kinds.

Having complex thinking associated with the teaching practice of mathematics teachers is essential to stimulate the thinking of educators in this area. By adopting a way of thinking that seeks to reconcile different dimensions of mathematical knowledge and its relevance in contemporary life, teachers can interweave distant concepts, contextualize problems in real situations, articulate teaching with different areas of knowledge and opt for different resources and strategies. In this way, teaching becomes dynamic, and, as a result, learning starts to make sense to the student.

We agree with Wechsler (2002) when he says that people think better "when they can have an image of the problem ... and it is recommended that we try to use visualization, associated with hearing and touch" (p. 225). We perceive the use of images as a strategy that enhances creative movements, which are not always predictable, nor can they be generalized and have a significant level of originality. Creativity can therefore be important

> to find solutions to problems and, at the same time, deal with all the issues related to complexities, logical and empirical contradictions, antagonisms, incompleteness, multidimensionality, the principle of organizing disorder, uncertainties, and randomness (Brandt, 2016, pp. 167-168).

Seeking solutions in a context of complexity leads us to a sense of building solutions. "Building" is action and, we would venture to say, action arising from feeling free, the freedom to create. Following Brandt (2016), the following are essential for creativity: "autonomy, personal flexibility; openness to experience; self-confidence; initiative and persistence; emotional sensitivity; and a background of knowledge" (pp. 168-169).

In this way, we can relate creativity to using images and representations in different languages that help us understand concepts. In this vein, for Moraes (2019), creativity "requires different forms of expression and materialization of the creative object, different languages, among them, bodily, playful, poetic, aesthetic, musical, meditative languages that

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lead the transdisciplinary subject to explore the richness of their interior" (pp. 87-88).

De La Torre (2008) also indicates some of the elements that make up a creative teacher, in particular, who seeks to: stimulate creative processes; promote learning through discovery; provide intellectual flexibility; help students to be more sensitive; promote reflection through divergent questions; have a more horizontal than vertical posture; establish relationships with reality through the handling of things; and encourage students to overcome frustrations. We agree with De La Torre (2005) that creativity can be understood as a potential that springs from the human being, and it is essential to establish relationships that value differences, diversity, and new ideas. Creative people are different from each other, but the pleasure they get from what they do is what makes them similar (Guérios et al., 2022).

Along with these elements that contribute to the composition of the creative teacher, it is also essential that teachers use their autonomy to "let the new spring forth" (Guérios, 2002), which is imbricated with the creativity of doing and being a teacher, in any space that allows communication and interaction between human beings, beyond the walls of the school.

Below we will briefly discuss creative thinking and the creative mode in teaching actions.

Creative thinking and teaching practice

Regarding creative thinking, Suanno (2012) says that schools can only be considered creative environments if those who work in them know, believe, and practice this type of thinking. From this perspective, we understand that for this to be possible, it is urgent and necessary for teacher training to be constantly moving, reconstructing their actions, imbricated with comings and goings about their thinking and teaching. Learning from the perspective of creativity takes place in an integrated way, in a great wheel of life, entangled with everyone and between everyone who makes up the school environment: the infrastructure, the relationships between school and family, the resources available inside and outside the school, among many other variables.

From creative teaching actions nurtured by creative thinking, students can be stimulated and challenged to think and act creatively, develop social responsibilities, and respect the multidimensions of each of their peers in an ethical and planetary way. In this sense, Morin (2012) proposes an ethic that welcomes the other that connects the other in their different needs - an ethic that, when brought into schools, transforms the human being, their understandings, as well as what makes up the process of empathy.

We agree with Suanno (2016) that, in order to fully develop creative thinking, it is necessary to consider the classroom environment or another space that belongs to the school, the relationships and interactions between students and their peers, between students and teachers and those who make up the school management, as well as the family and the external community. In a way, we can understand the organization of creative thinking as

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something initially disorganized, but as "our thoughts and feelings take shape, our ideas have an impact, our imagination materializes, our emotions emerge, and our authorship is born" (Amaral, 2011, p. 199).

We can relate the organizational movement of creative thinking to the self-eco-organization presented by Morin (2011), which represents the way of understanding that human beings organize themselves according to the relationships they have in the environment in which they live, which consequently affects their behavior. In this sense, the school environment is made up of self-organizing processes which, based on reflection, action, flexible strategies, and creative thinking, are "fertile ground" to allow creativity to flourish in students and teachers since in this space there are interactions and relationships between individuals that are oriented in this way, which makes it possible to create creative strategies.

According to Guérios et al. (2022), the creative way teachers think and act in their teaching practices interferes with how students participate in the proposed practices by seeking new paths that make sense and lead to learning for life. Moreover,

> students' creativity can be thought of as being stimulated by innovative practices proposed by teachers to sensitize them, creating a space that encourages participation, is relaxed, and provides the construction of knowledge that makes sense for life (Guérios et al., 2022, p. 38).

Solving problems, recreating, inventing, creating, and thinking differently are actions that permeate creative thinking. Likewise, they should be part of teaching practices in the classroom. In this sense, De LaTorre (2005, p.113) emphasizes that "creative thinking is a type of mental energy that can be increased, inhibited, specialized ... through human stimuli and eidetic images". The author also points out that it is possible to "lose a lot of our mental and creative energy due to the lack of 'synthesizing tools' that turn it into useful ideas for solving problems or improving our professional and human activity" (De La Torre, 2005, p. 113).

In this case, we can relate the "synthesizing instruments" to the creative pedagogical practices pointed out by Guérios et al. (2022), which emerge from the "bonds and interactions between the individuals belonging to the school environment that make up a complex web ... resonating with the development of complex thinking from Edgar Morin's perspective" (p. 36). Furthermore, teachers' sensitivity in their outlook, their thinking about students, and their autonomy in organizing strategies that seek to learn through creativity are essential for cultivating creative thinking, providing a creative environment, and, in this way, integrating the individual-nature-society triad.

Here, teacher autonomy refers to pedagogical autonomy when organizing and restructuring didactic practice, which can help develop teachers' creative thinking and, as it becomes frequent, all individuals will learn and teach to explore creativity inside and outside the school environment.

From this perspective, we present the modeling method used to organize, analyze and

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reflect on the research data that resulted in teacher creativity and teacher autonomy as aids for teacher training from a complex perspective, according to Edgar Morin.

Modeling and the voices of the participants

Six public school teachers from Curitiba and the Metropolitan Region, who teach mathematics in elementary and high school's 6th to 9th grades, participated in producing research data in 2019. These participants, aged between 36 and 50 and with an average of 12 years of teaching experience, were willing to collaborate with the research and took part in a continuing education course, in the form of a university extension course, called "Teaching Geometry in Basic Education and its relations with the other fields of school mathematics," organized by the researcher and her supervisor specifically for data production and offered by the Federal University of Paraná, so that the participants could be valued through certification, totaling 20 hours. In addition, the research participants met the following criteria: be a teacher who teaches mathematics; teach in elementary and/or high school; deal with geometry content; have availability; and sign the Informed Consent Form.

The extension course was organized into four practical meetings and three theoretical meetings in the form of conversation circles, all audio-recorded and later transcribed.

> The practical meetings took place in person at the Federal University of Paraná, where the participants explained their ideas, reflected, and proposed activities relating to didactic practice in Geometry. The theoretical meetings were based on previous readings and activities developed between meetings (Góes & Guérios, 2022, p. 09).

Except for the first practical meeting, each new meeting, in the form of a conversation circle, was organized through the systematization of the previous meetings, carried out by the researchers, considering what was said in the previous meeting and the notes on the activities carried out. This dynamic ensured fluidity between the meetings, allowed for recursion in each meeting, as well as meeting the expectations of the participants, who saw themselves as taking part in their own training.

After transcribing audio, the initial ideas were systematized and generated speech clippings in the pre-analysis phase before we applied the five steps of the modeling method. This pre-analysis phase,

> by floating reading the transcripts in search of the proximity of the participants' voices to the organizational [theoretical] categories derived from complex thinking and/or to 'elements' of complex thinking, according to Edgar Morin, gave rise to emerging categories. Next, the documents analyzed were chosen, i.e., the texts produced by the transcripts of the roundtables, the interviews, and the activities produced by the participants during the roundtables, by grouping them by similarity of themes (Góes, 2021, p. 92).

The organizational categories were: fragmentation; transdisciplinary; recursivity; retroactivity; and flexibility and unpredictability. These are theoretical categories derived from the assumptions of complexity theory and are aligned with the aim of the research. They were created to organize the data and are related to teacher training. The organized data

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analysis led to the emergent categories: fragmentation; reflection on teaching action; flexibility and unpredictability; teaching practices with a geometry approach; trans disciplinarity; and innovative practices. For this article, we will base ourselves on some of the clippings used in the emerging category "didactic practice with a geometry approach," in which it was possible to verify creativity as one of the subsidies emerging from the voices of the research participants. In this way, we will describe how this movement of analysis was constituted and how the creative thinking of teachers who teach mathematics can contribute to creative actions in the classroom.

For us, modeling is seen as a complex, flexible, and dialogical method for organizing, analyzing, and reflecting on the data produced in a research project, making it possible to reflect on the data produced and the graphic representation itself, and it can be used by all areas of knowledge that deal with phenomena considered complex and that seek a method with these characteristics based on complex thinking, according to Edgar Morin (Góes & Guérios, 2022, p. 16).

The following are the five steps of modeling, according to Góes and Guérios (2022):

- Step 1: The "reorganization of the clippings" consists of grouping the clippings of the participants' voices by theme, carried out in the pre-analysis, in which "the clippings are reorganized, verifying which of them are close to the pre-established categories that generate new categories, which we call emerging categories and which thus characterize their selection";
- Step 2: The "analysis of the clippings" takes place through the theoretical link chosen by the researcher and the "reorganization of the clippings of the participants' voices, which made up the reflections of the organizational category" in question;
- Step 3: The "definition of keywords and construction of an associative framework" is based on the emergence of themes observed by the researchers from the analyses in step 2, which "were emphasized by the participants during the data production and which we call keywords." The associative framework is designed to systematically organize which of them [keywords] are related, based on the analyses carried out on the clippings;
- Step 4: "Construction of the graphic representation" is the process of drawing up the graphic representation that best indicates "the relationships established by the researcher." It is a process of free construction by the researcher, in which it may be necessary to use more than one attempt to transform the theoretical relationships into a drawing;
- Step 5: "Reflective description of the graphic representation" is the fifth and final step in which "reflections on the graphic representation" are presented following the theoretical framework of the research (p.10).

In this step 1 of the modeling process, we will present the reorganization of some

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clippings from the voices of the research participants. We will start with Daiane's voice, as she presents the reality she experienced in an elementary school class, and Suzan and Bia's, in elementary school, during their geometry classes, for which they chose to use the Tangram.

Daiane used the Tangram to teach geometry based on folding, highlighting geometric shapes as the folds were made, as in the case of the appearance of the triangle, for example. She said: "I use folding a lot with the little ones; here, it forms a triangle, and I show them as they fold it" (Third audio, p. 21).

During the round table discussion, Bia talked about the work she had done in a 6th-grade class, in which she suggested that the students each build their own Tangram out of paper and assemble various figures. As a result of this didactic action, to hold an exhibition at the school, the idea was expanded so that, with the students together, it would be possible to assemble a giant Tangram with paper of the same color. Figure 1 shows the activity.

Figure 1: *Didactic practice with Tangram*
Source: Bia's Collection (2018)

By building the Tangram, Bia covered plane geometry, the classification of polygons, concepts of area, the perimeter of figures, the history of the Tangram, and the study of angles and vertices of the figures formed, emphasizing the analysis of fractions.

As the conversation circles went on, the participants continued to talk about their strategies in the classroom. When asked about her teaching actions, Suzan shared that, for the construction of the Tangram, she chose material derived from wood, as shown in the following transcript:

> I worked with Tangram with the sixth and eighth graders, and I was able to work a lot with the content. I gave them [students] the Tangram in MDF and asked them to paint the whole structure. I showed the students how to form a puzzle with their chosen design. The Tangram was very useful; I worked a lot with geometry. You can also work on parallelograms with eighth graders. I can develop a lot of geometry with the eighth graders. (Second audio, year, p. 05).

Using her teaching strategy, Suzan introduced 6th and 8th-grade classes to the history of the Tangram and the classification of the perimeter of the flat figures derived from the

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puzzle. In addition, she asked the students to present research on the various legends about the Tangram to share with their peers and to freely paint their puzzles with the color, texture, and composition they wanted. According to Suzan, the proposed activity motivated the students to organize the arrangement of words, phrases, letters, and numbers (Figure 2): "The students were very excited. They assembled the images of the words and numbers on the floor, and then they were able to take the Tangram for themselves". (Online interview, p. 01).

Figure 2: *Composition with Tangram*
Source: Suzan's Collection (2019)

The following year, Suzan proposed using leftover wood-based materials in activities with 8th-grade classes to explore geometric concepts and the student's creativity.

> There is a huge bag; there must be more than 100 triangles of the same size. I was just thinking about making a mosaic, I only have two classes, and I think I can work with it... they are equilateral triangles, and they're all the same size. I am going to work on geometry with the eighth graders now. I'll be working on geometry in the third and fourth terms. With them [students], they learn everything visually. (Second audio, p. 08).

Checking the leftover material, Suzan realized there were enough pieces to assemble another nine complete puzzles for each of the three 8th-grade classes she taught. Suzan organized the students and asked them to research the Tangram's history, the puzzle's assembly, and the game's authentic customization (Figure 3).

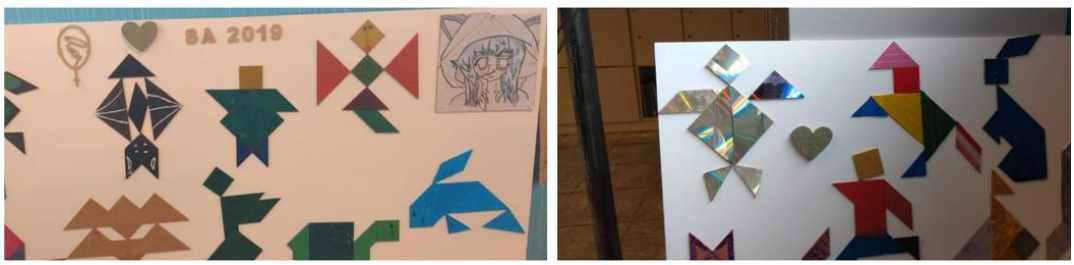

Figure 3: *Customizing the Tangram*
Source: Suzan's Collection (2019)

The content Suzan covered was the study of triangles, their elements, internal and external angles, the study of parallelograms, area, and perimeter of all the figures that make up the puzzle. At the end of the Tangram activities, Suzan put together a panel to be displayed during the parents' meeting.

Based on the interactions between the participants in the conversation circles, Matheus brought up for discussion two activities developed in high school classes, made

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possible by his autonomy to make one of his five weekly classes available for teaching geometry. For the first of them, about the study of volume and total area of geometric solids, "he first asked the students to research the volume of solids, including the definition and examples, so that they could develop what was proposed in the classroom" (Góes, 2021, p. 164). Matheus then built a solid filled with sweets, and the students were organized into groups and challenged to find out the measurements of the solid just by looking at it on a table. The team that came closest to the correct measurements would win the treats.

With this strategy, Matheus sought to optimize his time to cover the class content and give the students a practical lesson. In addition, Matheus noticed that throughout the school year, the students mentioned the practice of the solid filled with sweets when approaching other content, as was the case with the study of the pyramid trunk.

The second practice Matheus reported was with 2nd-year high school students on building a solid with a lid whose capacity was equal to one liter. To check that each of the solids brought by the students had a capacity of one liter, Matheus used the following strategy "I brought the beans in the jar, and I asked where the solids were. It had to have a lid. And when I approached to check, there was this circle of students waiting to see if the beans would overflow." (Third audio, p. 33). Here, Matheus used the strategy of taking grains of beans to pour into each solid built by the students and thus check that the solid was the correct size for a liter. Usually, you can make a direct conversion and indicate that one liter is equivalent to one kilogram since the density of water is one kilogram per liter, which was the one Matheus adopted during the didactic practice when checking the volume of the geometric solid.

Matheus allowed the students to choose the solid and the material to build it with. There were some fragile solids, others more elaborate, some very large, others very small, most in the shape of a cube, others used milk cartons, and one of the students built a wooden cone with his father's help, a carpenter.

In the next section, we will present step 2 of the modeling process - the "analysis of the cut-outs" and its relationship with the creativity and creative thinking of the participants, who are teachers who teach mathematics.

Analysis: the creative thinking present

Based on the clippings of the participants' voices indicated in the previous section, we present below the analysis of the emerging category, "teaching practice with a geometry approach," based on complex thinking and emphasizing creativity.

When we analyzed the teaching practices of Daiane, Bia, and Suzan, we saw creative thinking in the different organizations of the teaching actions, in the way they brought the game into the classroom to explore geometry concepts, in the way the movement of teaching geometry was constituted, whether based on the history of the puzzle or through attempts to make the folds.

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Creativity was present in the choice of materials used to build the games, both paper and wood-based materials. Throughout Suzan's practice, creative thinking was shown when she reused the leftovers from the puzzle in order to be able to reuse them with other classes the following year (2019) from the practice carried out in 2018. The teacher also developed the students' creativity when she asked them to customize the puzzle as they wished, giving them the freedom to create the artistic composition they thought of. This movement of the students' creativity that Suzan made possible is related to what Brandt (2016, p. 175) refers to as "brainstorming," a technique that allows the development of the student's creativity. We understand that within the classroom, "brainstorming" can happen in the class as a whole, where the teacher is considered the mediator of the ideas that emerge from the teacher's actions.

Suzan's creative nature meant that, instead of discarding what was left over from the Tangram practice, she opted to reuse the puzzles, which is directly related to planetary awareness, which Morin (2018, p. 65) says can help "to teach how to assume the human condition, to teach how to live." In addition, Suzan's creativity is related to being flexible because even after planning the lesson with the 6th-grade classes and coming across the leftover wood-based material, she developed another didactic practice with the 8th-grade classes. We understand that Suzan went beyond what she had thought and planned, which shows that she always had a thinking mind during the discussions.

With the practice of geometric solids, Matheus optimized the time for pedagogical planning and allowed the students to search for the theme, think creatively, and develop strategies to discover the measurements, organize themselves and systematize their actions in groups. It also led students who had previously been "distant" during the activities to get involved with their peers: "Even students who did not do much participated. Colleagues demanded of each other and organized the steps among themselves, 'either you are going to do something, or you are going to measure the solid'" (Third audio, p. 27).

This creative movement on the part of the students is intertwined with Matheus' sensitive eye, flexibility, and autonomy in proposing this creative didactic practice, in which the teacher went beyond the study of geometry: he allowed each student to be a protagonist in the process of constructing knowledge, made them a constituent part of the classroom as a whole, emphasized learning aimed at the formation of the individual and collaborated in living together in society.

One of the reasons why Matheus continues to dedicate one lesson a week throughout the year to teaching geometry is the feedback he gets from the students' development, reinforced by the reports of his peers, who then go on to teach them in future years,

> and I have already heard from other teachers, "Wow, I have several students in my eighth-grade class who know various things, various construction concepts, they know what a mediatrix is, a bisector, they even know how to work with materials."... One thing I have been doing at school and I do not intend to give up is one geometry lesson a week. (First audio, p. 13).

Looking at himself and his actions, Matheus, in a retroactive process of comings and

DOI: 10.20396/zet.v31i00.8672172

goings, reveals contentment, saying, "I got on very well" (First audio, p. 13) by creatively carrying out his actions in the classroom and using his autonomy to organize and plan his geometry lessons.

Throughout the reports of the didactic actions shared by Suzan, Bia, Daiane, and Matheus, we see that they possess the characteristics brought up by Brandt (2016) "regarding autonomy, personal flexibility; openness to experience; self-confidence; initiative and persistence; emotional sensitivity; and baggage of knowledge" (p. 168) and realize how fundamental these characteristics are for the development of creativity.

Based on the analysis, we now present step 3 of the modeling process, which consists of "defining keywords and building the associative framework." Given the analysis of the clippings of the participants' voices, we have indicated the following keywords, which will enable us to construct the graphic representation: creativity; teacher autonomy; teacher; strategy; student; student motivation. Based on these keywords, we organized the following associative chart (Chart 1).

Chart 1: *Associative Chart*

Keywords	**Creativity**	**Teacher autonomy**	**Teacher**	**Strategy**	**Students**	**Student motivation**
Creativity	X	X	X	X	X	X
Teacher autonomy	X	X	X	X		
Teacher	X	X	X	X	X	X
Strategy	X	X	X	X		
Students	X		X		X	X
Student motivation	X		X		X	X

Source: The authors (2023)

It is important to point out that the keywords emerge from the analysis of the clippings of the participants' voices and are thus named based on the organization of these clippings into groups of observed themes that emerge from them. This process of organizing and analyzing which keywords may emerge is directly related to the view of the modeler-researcher and the theoretical domain in which the research is inserted - in this case, complexity. In this way, we understand that the keywords are related to the construct "Being creative" and, consequently, to creativity and creative thinking in teaching practice.

Based on Chart 1, in the next step, we will present the graphic representation (Figure 4) of the emerging category "teaching practice with a geometry approach," with creativity as the focus in the participants' voices.

DOI: 10.20396/zet.v31i00.8672172

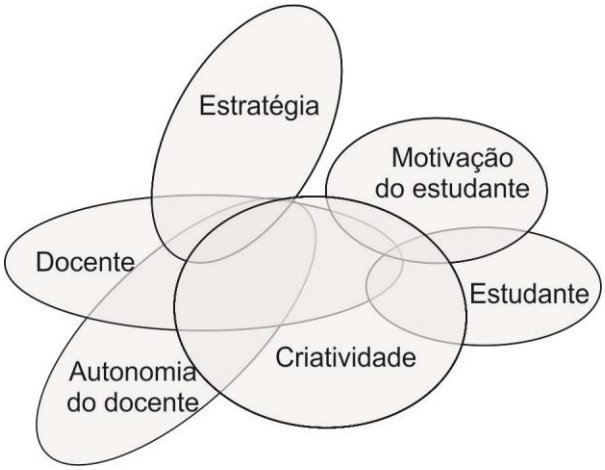

Figure 4: *Customizing the Tangram Modeling*
Source: The authors (2023)

Based on Figure 4, derived from analyzing the participants' voices, we present the reflective description. The modeling reveals, from the voices of the research participants, relationships between creativity and creative thinking with teacher autonomy, student autonomy, the strategies proposed by the teacher, student motivation, as well as the interactions between the student and their peers, and the relationships between the teacher and the students, as in a diversity of threads that weave the construction of knowledge, each with its own importance. Thus, during the analysis of the emerging category "didactic practice with a geometry approach," focusing on the creativity present in the participants' voices, "creativity" and "teacher autonomy" appear as essential and guiding aids for complex teacher training.

Furthermore, based on the metamodeling, according to Góes (2021), obtained "from the perspective of the researcher-modeler, when analyzing the production of data, given the interaction between her perceptions and the events experienced during the conversation circles" (p. 228), it was possible to determine the construct "Being creative" based on the relationships and articulations that the subsidies "creating and recreating," present in another emerging category of the research, and "creativity" established. It is worth noting that the construct "Being creative" is directly related to "teacher autonomy," with the teacher "as the subject in the spotlight, because it is from the free choice to be open to the new, the uncertain, the unpredictable, that they can develop didactic practices in geometry that make a difference in students' lives" (p. 230).

Thus, based on the analysis of the participants' voices, we can highlight that they have these elements at their core, i.e., being a teacher is full of complexity, as they act in a complex way. In addition, the construct "Being creative" is essential for complex teacher training, especially didactic practice in mathematics, which results in creative, ethical, planetary, and supportive citizens who are motivated to face the challenges of today and give meaning to life.

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Weaving in considerations

This article has sought to present the results of doctoral research to support the development of constructs for the training of mathematics teachers based on complexity and with a view to the development of complex thinking and how this thinking can be present in the didactic practice of these teachers.

Organizational categories emerged from the voices of the participants, and for the purposes of this article, we will consider some clippings of the voices from the category "Teaching practice with a geometry approach." The aspects observed during the analysis through modeling in the light of complex thinking indicate that the participants present elements of complexity in their actions in the classroom concerning the movement of knowledge construction with a geometry approach, such as creativity, teacher autonomy, flexibility, and sensitivity.

About the didactic practices with a geometry approach at the primary and secondary school level described here, it was possible to verify the creative way in which they thought, organized, planned, and executed the practices, as well as allowing students to be included in the creative process of carrying out the phases of the activities and instigating creativity in the choice of materials and resolution strategies.

Teacher autonomy was present throughout the process of the strategies adopted by the teachers, whether through organization or restructuring and also through creativity in the cognitive processes of the action, by being open to the new that emerged from the didactic practice. Moreover, by allowing themselves to be open to the new, the participants considered unpredictable situations, turning them into mathematical learning situations while transforming the classroom into a possible environment for understanding the world's complexity.

Thus, we understand didactic practices as activities that provide an experience of wholeness, in which the subject is wholly involved in their multidimensional and needs structural flexibility of action, thought, and cognitive fluency when experiencing a given process (Moraes, 2015, p. 172).

According to Moraes (2015), the most crucial thing in creative activity is the "moment lived, the process, the experience, the sensations, the focused attention, the degree of satisfaction obtained and not just the result or product evaluated by society" (p. 172), which was verified by the reports of the research participants and also by the way the students carried out the proposed activities. Creativity is seen as an essential movement, as it allows the sensitivity to be stimulated, creative thought processes to be established and reinforces the will and curiosity to keep students attentive and participating in didactic practice, as well as providing an education that is more intertwined with the vision of/the world and less fragmented.

The modeling method made it possible to verify that the critical elements in the participants' voices were "teacher creativity" and "teacher autonomy," which are essential for

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complex teacher education. Furthermore, through the relationships and intertwining of the "creating and recreating" and "creativity" inputs from the perspective of metamodeling, it was possible to establish the construct of "Being creative" since we understand creativity as one of the dimensions of the human being, which can be more - or less - evident in teaching actions.

Therefore, we emphasize that it is necessary for teachers to bring elements of complexity permeated by creative thinking into their teaching practices and to be open to the new in order to support students and encourage them to develop creativity and autonomy, which can lead to critical and reflective thinking in the process, contributing to learning beyond the school walls.

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