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Collective mathematical creativity: the role of mediation towards shared creativity

Criatividade coletiva em matemática: o papel da mediação rumo à criatividade compartilhada

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Abstract

In a context that demands skills focused on collective and creative work, research presents itself as an unusual alternative, focusing on the collective dimension of creativity. The purpose was to show characteristics of communicative interactions favorable to the emergence of shared creativity in mathematics and made possible by the teaching mediation of students in the 5th year of elementary school. It was guided by the qualitative methodology, using a creativity test and a semi-structured script for conducting focus groups as data collection instruments. Data were analyzed using Critical Discourse Analysis, listing categories of creative sharing during the mediated resolution of open mathematical problems. It was noted that collective work is characterized by the negotiation of meanings, positive affection, offering feedback, leadership, conscientiousness, and the use of ideas. It is concluded that the teacher plays an important role in guaranteeing interaction patterns aimed at the collective construction of mathematical knowledge.

Keywords: Mathematical Creativity; Shared Creativity in Mathematics; Teaching Mediation; Mathematics Education

Resumo

Em um contexto que exige habilidades voltadas para o trabalho coletivo e criativo, a pesquisa apresenta-se como alternativa incomum, focando na dimensão coletiva da criatividade. Objetivou-se evidenciar características de interações comunicativas favoráveis à emersão da criatividade compartilhada em matemática e possibilitadas pela mediação docente de alunos do 5° ano do ensino fundamental. Guiou-se pela metodologia qualitativa, utilizando-se como instrumentos de coleta de dados um teste de criatividade e um roteiro semiestruturado para condução de grupos focais. Analisaram-se os dados por meio da Análise do Discurso Crítica, sendo elencadas categorias do compartilhamento criativo dado na resolução mediada de problemas matemáticos abertos. Notou-se que o trabalho coletivo é caracterizado pela negociação de sentidos, afeto positivo, oferecimento de

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feedbacks, liderança, conscienciosidade e aproveitamento de ideias. Conclui-se que o docente tem papel importante na garantia de padrões de interação voltados para a construção coletiva de conhecimentos matemáticos.

Palavras-chave: Criatividade em matemática; Criatividade Compartilhada em Matemática; Mediação docente; Educação Matemática.

Introduction

For a long time, creativity was considered to be an individual attribute, and research sought to characterize the creative subject and highlight how they think and produce ideas. Currently, much of the creativity research has focused on the individual, aiming above all to distinguish the personality traits of people who show high creative performance (Neumann, 2007). The historical context has favored research that takes individual aspects into account, to the detriment of considering creativity as a process that can take place collectively.

In its origins, the first reflections on creativity emerged from a mystical perspective, which considered creative people to be chosen by divinities to receive this gift (Lubart, 2007). Later, in the 18th century, this phenomenon came to be seen as an attribute of a privileged few, considered geniuses, who were born with creative abilities (Carvalho, 2015). As Glăveanu and Lahlou (2012) understand, the "he-paradigm" or paradigm of the otherness of genius is established, in which creativity is treated as a hegemonically masculine genius, describing it in an elitist, existentialist, and even pathological way. By looking at the subject from the social and cultural context, the supernatural and innatist considerations of this phenomenon have therefore contributed to the hegemonic approach that considers creativity as something that develops in the mind of the individual (Glaveanu, 2014).

Despite the dominant consideration of creativity as something individual, we must take into account that technological, cultural, and social changes have occurred at a much faster rate, requiring people to have skills geared towards collective work and the use of creativity to solve complex problems (OECD, 2021). And formal learning spaces are receiving, for the most part, digital natives, students from generations Z and Alpha (McCrindle & Wolfinger, 2010), who emerge in a context of the abundance of multiple and advanced technologies at their disposal, therefore immersed in a globalized, communicative and collective world, in which people are, at all times, participating in the various moments of everyone's lives.

In this context of the need to change approaches, from the I-paradigm, an individualistic perspective of creativity, towards the we-paradigm, considering the social as an important constitutive factor of creative actions and minds (Glaveanu, 2014), this research presents itself as an unusual alternative in the midst of the ocean of investigations aimed at analyzing the person, the environment, the process or the creative product. We will try to highlight the collective dimension of creativity in mathematics, known as shared creativity in mathematics, with its nuances, barriers, and possibilities for the construction of mathematical

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ideas in groups of students involved in a social context. In this special issue, those looking to delve into the literature in the field and get closer to what has been researched in recent years will find a somewhat original approach, focusing on creativity built by many hands (Carvalho, 2019) in an atmosphere of dialogic and sharing of ideas.

Our central objective is to highlight the characteristics of communicative interactions that are favorable to the emergence of shared creativity in mathematics and made possible by teacher mediation during the process of collective creativity in the mathematics classes of 5th-grade students in a public school. We will try to analyze how, in situations of solving open-ended mathematical problems, the teacher can interfere, setting up patterns of interaction that allow everyone to participate on equal terms.

Creativity in mathematics: historical aspects and the hegemony of the individual conception of creativity

In 1999, Professor Hartwig Meissner organized an International Conference on Creativity and Mathematics Education in Muenster, Germany, attended by around 80 people from more than 20 countries. Following this initiative, the years that followed saw international conferences in which creativity, mathematics education, and giftedness were discussed by various nations. One of the results of the 2008 conference was the election of a working group to create the International Creativity and Mathematical Giftedness Group - IMCG. Finally, the IMCG was established during the Sixth International Conference on Creativity in Mathematics Education and Gifted Education, held in Latvia in 2010. These chapters in the current history of research into creativity in mathematics mark a field of study that has been spreading around the world, allowing researchers and teachers to gain valuable knowledge that can help educational institutions develop important skills for coexistence in ever more technological and collective societies.

Since the IMCG can be considered the main vehicle for scientific communication in this area of study, with research from various countries and "the expression 'creativity in mathematics' in its name, emphasizing its field of action" (Gontijo, Fonseca, Carvalho & Bezerra, 2021, p. 15), we can turn to the studies published in its annals to affirm the existence of hegemony of research that deals with creativity from an individual perspective, with rare investigations that consider the collective. Some authors (Leikin & Pitta-Pantazzi, 2013; Carvalho, 2019; Gontijo, Fonseca, Carvalho & Bezerra, 2021) have sought to analyze, by reviewing the literature, the directions in which research into creativity in mathematics has taken. What they have in common is the categorization of approaches that corroborate the fact that research on collective creativity is scarce.

Leikin and Pitta-Pantazi (2013) show that this field of research has been divided into four distinct approaches: pragmatic, mainly dedicated to studying ways of developing creativity; psychometric, to assess subjects' creativity through individual tests; cognitive,

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consisting of studies aimed at analyzing the cognitive processes associated with creative reasoning; and the social personality perspective on creativity, emphasizing affective factors related to creativity, as well as sociocultural characteristics. Despite citing Sawyer (1995) to affirm that creativity emerges from a complex interactional process, the examples of research presented by the authors do not demonstrate how interactive processes can influence the emergence of collective creativity.

Carvalho (2019) surveyed ICMG databases and annals (from 2014 to 2017), classifying empirical studies in three ways: in terms of methodology (qualitative, quantitative, or mixed); in terms of the intended purpose (pragmatic - to point out alternatives for developing creativity; psychometric - to measure and/or relate measurable constructs at the psychological level; procedural - to point out aspects of the creative process or phases in which it is constituted); and finally, in terms of focus (individual or collective). The results point to the tendency for research to approach the subject in a quantitative, psychometric way and to focus on the individual, signaling the small representation of qualitative research and research that addresses socio-cultural factors.

Gontijo, Fonseca, Carvalho and Bezerra (2021) carried out a study in which they located research on the world stage and categorized research focuses in the area of creativity in mathematics, based on the research presented in the IMCG. The authors present four types of groups, which are not mutually exclusive, into which they classify research into creativity in mathematics: as a methodological resource for teachers; as a means of constructing manipulative materials; as a result of the classroom climate; as a means of constructing symbolic models based on problem-solving. This study also concludes that the collective aspect is under-represented.

The collective dimension of creativity in mathematics

Contrary to the current trend of considering mathematical creativity from an individual perspective, Sinclair, De Freitas and Ferrara (2013) present a different perspective when considering creativity in the mathematics classroom, emphasizing "the social and material nature of creative acts" (p. 239). Authors such as Sawer (2007) and Glăveanu (2014) have sought to demonstrate that creativity is impossible outside of a social context. The conceptual basis they use to approach creativity from a collective perspective is, above all, the contributions of Csikzentmihalyi (1996), who points out that something can only be considered creative if it is validated by society.

Glăveanu (2014) considers that creativity extends and is distributed among multiple actors, creators, places, and times. The author understands that the mind is still the locus of creativity, but emphasizes that this phenomenon never occurs in isolation. Therefore, from this perspective, creativity can be seen as an important process in the transformation/maintenance of the world in an interrelationship between creative individuals

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and collective decisions: "Leaders, visionaries, and revolutionaries embody creativity, to different degrees and with different consequences, but it is the collectives that change the world by taking risks and making bold and unusual choices" (Glăveanu, 2018, p. 157).

In the field of mathematics education, few studies refer in any way to the collective dimension of creativity. Reinforcing this statement, it can be seen that, in the latest version of the IMCG (2022), this topic is at a disadvantage compared to the individual approach to the construct. With a specific focus on this aspect, we can mention the studies by Levenson (2011), Carvalho (2019), Carvalho and Gontijo (2022a, 2022b), and Aljarrah and Babb (2022).

Levenson (2011) analyzed the collective creativity of a classroom, evaluating the students' problem-solving output through fluency (number of solutions presented by the group), flexibility (use of different strategies and adaptation of previous solutions), and originality (unique solutions). The author also analyzed the role of the teacher in promoting collective mathematical creativity and the possible relationship between individual and collective mathematical creativity. She concludes that collective creativity is partly the result of a climate that allows the free flow of ideas and a teacher who is flexible enough to allow and promote this climate. She also concluded that collective work can encourage students to take risks in search of new ideas so that by promoting creativity in mathematics in groups, it can also be promoted in each individual.

By observing the collective work of a class of students in solving open-ended problems related to probability, Carvalho and Gontijo (2022a) investigated how children aged 10 and 11 construct mathematical ideas through argumentation. By using validity arguments rather than power arguments, the respondents were able to establish dialogic conversations favorable to the collective production of mathematical knowledge. Through attentive listening, and the ability to use mathematical knowledge to defend ideas and participate creatively and critically in the processes of negotiating meanings, it was possible to construct concepts and solve mathematical problems involving the universe of probability.

In another study, Carvalho and Gontijo (2022b) investigated the collective work of three students, one of whom had autism spectrum disorder (ASD). The research found that, by helping and being helped by their peers, the trio was able to produce creative ideas when solving open-ended problems, with the ASD student helping to construct unusual solutions due to having unique creative thinking characteristics such as resorting to non-lexicalized verbal knowledge, thinking through analogies, among other singularities that helped the team perform well.

Aljarrah and Babb (2022) analyze a task-based interview in which students engaged in an activity designed to promote collective creativity, exploring the potential of switching between different metaphors of arithmetic (numbers as a collection of objects, as an object composed of others, associated with distance or as positions on a number line) to trigger

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creative acts. The authors consider collective creative acts as "particular types of (co)actions and interactions of a group of students while working on a mathematical problem, which includes possibilities for expansion (broadening the students' horizon, gaining new insights based on previous insights) and divergent thinking (considering many potential paths, looking in several directions, going beyond the given conditions and information of the problem and thinking outside the box).

The role of mediation towards shared creativity

The school, like other spaces of social interaction, is made up of people and discourses that carry within them power relations, which are often asymmetrical. Foucault (1992) warns that the power involved in macro-structures only acquires great proportions due to the set of micro-powers involved in everyday life, such as, for example, in day-to-day classroom life. Based on Van Dijk's (2015) studies, Carvalho (2019) categorized four ways in which power can be exercised in the school environment, whether in the relationship between teacher and student or in the relationship between students and their peers.

a) Illocutionary force: direct control over action is obtained through slogans such as commands, threats, laws, regulations, instructions, recommendations, and advice to convince the dominated of something.

b) Persuasive force: use of rhetorical mechanisms such as repetition and argumentation to convince the dominated to adhere to ideas.

c) Limited access to discourse: the more powerful subject determines forms of interaction in which not everyone is allowed to speak.

d) Control of turn-taking: the dominator decides who speaks when they speak and how they speak.

Given that asymmetrical power relations can occur in a classroom (Carvalho, 2019), it is necessary to intervene so that everyone has the same opportunities to construct ideas and communicate them. This ideal process of constructing mathematical knowledge has been called Shared Creativity in Mathematics, understood by us as: "a phenomenon that occurs in collectives in which people come together to carry out some kind of activity, bringing their marks and contributing to the cognitive and affective sharing of their life experiences" (Carvalho, 2019, p. 94).

In a reality in which math classes are usually structured by patterns of interaction dominated by the transmission of information (Guerreiro, Ferrreira, Menezes & Martinho, 2015), teacher mediation, aimed at managing relationships, must therefore take place to establish democratic power relations, guided by the collective construction of mathematical knowledge. As previously argued, the young people who populate classrooms arrive with a huge amount of information. Therefore, classes focused exclusively on transmitting

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information are outdated and disconnected from the current needs of digital natives.

Methodology

This is a qualitative investigation, from an interpretative perspective, to explore the contents involved in the speeches and protocols presented by 5th-grade elementary school students when they solve open-ended problem situations in trios. This text is part of a larger study carried out as part of a doctorate in education completed in 2019, in which students were investigated while solving problem situations at three different times: working individually, working in trios without any intervention, and working in trios with a power mediation methodology.

Here, we will present the results of the third way of working: when they were subjected to the Creative Sharing Methodology (CSM), since in the other ways of working we noticed the emergence of asymmetrical power relations that hindered collective work. We analyzed protocols with the answers presented by the teams, the discourses established during the work and the discourses constructed during focus groups held after the work with problem-solving. Backes et al. (2011) consider the focus group to be a group interview in which interaction between the participants is essential for the method's success. Therefore, for data collection, the following instruments were used:

a) Shared Creativity Test (CCT), made up of open-ended problems and consisting of 3 versions, one for each type of situation the students were subjected to. For this study, the third version is presented, which is made up of three items, as described in Figures 1, 2, and 3.

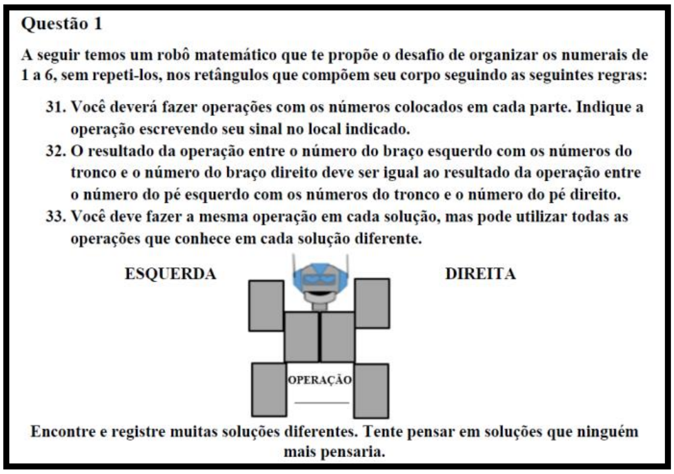

Figure 1 - Item 1 of Version 3 of the CBT
Source: Carvalho (2019).

b) a semi-structured script for conducting the focus groups. These interviews were conducted after the participants had answered each version of the math creativity test. The script is made up of questions that seek to gather data on the participant's perceptions of the

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interactions that take place during problem-solving, allowing the respondents to feel authorized to express their impressions of the constitution of democratic relationships based on validity arguments or, on the contrary, to announce the occurrence of asymmetrical power relations.

Questão 2

As crianças de sua escola participarão de uma gincana. Cada turma irá fazer uma bandeira para representar sua equipe. Porém é preciso seguir algumas regras.

1. **As bandeiras devem ter formato retangular e precisam apresentar 3 cores diferentes.**
2. **Cada cor precisa ocupar a mesma quantidade de espaço da bandeira.**
3. **Utilizando linhas retas, os alunos podem dividir o retângulo em 3 ou mais pedaços de tamanhos iguais e de formatos iguais ou diferentes (triângulos, quadrados, retângulos, etc.).**

Imagine que você foi contratado para desenhar as bandeiras para cada uma das equipes. Desenhe o máximo de bandeiras diferentes que você puder:

Figure 2 - Item 2 of Version 3 of the CBT
Source: Carvalho (2019).

Questão 3

Em uma fila no terminal rodoviário existem 90 pessoas esperando para embarcar em um ônibus que acaba de chegar. Pedro é o 59º colocado nessa fila e sabe que o ônibus comporta 42 pessoas sentadas e 18 em pé e não pode sair com um número maior de passageiros, sejam sentados, sejam em pé. Quando começou o embarque, outras 13 pessoas cortaram a fila. Crie muitos problemas matemáticos, diferentes, utilizando as informações acima.

Figure 3 - Item 3 of Version 3 of the CBT
Source: Carvalho (2019).

The collective work with mediated interactions was carried out using the Creative Sharing Methodology (CSM), inspired by the collaborative learning model of Van den Bossche, Gijselaers, Segers, Woltjer, and Kirschner (2011), which consists of directing the students' work through four stages, as can be seen in Figure 4.

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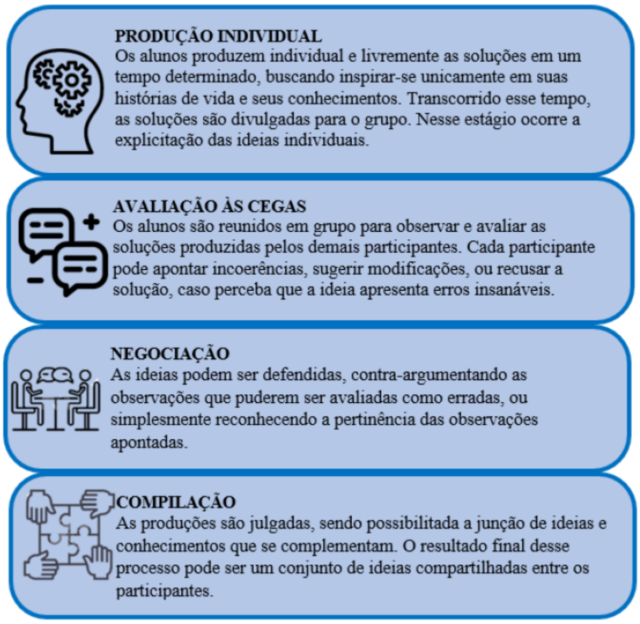

Figure 4 - Creative Sharing Methodology
Source: Carvalho & Gontijo (2022a). EIA & D

A class of 24 fifth-graders took part in the study, purposely arranged in eight trios. After collecting the informed consent forms signed by the parents, we proceeded to the problem-solving sessions and focus groups, in which we used the data collection instruments shown in image 4.

Figure 5 - Research procedures
Source: Carvalho (2019).

The communicative interactions were evaluated using Critical Discourse Analysis (CDA), and categories were identified which can be classified according to characteristics favorable to the emergence of shared creativity in mathematics resulting from teacher

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mediation:

> ... a special intonation, visual and sound properties (color, typography, image configurations, music), syntactic structures (such as active and passive), lexical selection, semantics of presuppositions or descriptions of persons, rhetorical figures or argumentative structures and, on the other hand, the selection of specific speech acts, politeness moves or conversational strategies (Van Dijk, 2015, p. 14).

It is understood that ADC "refers to a set of interdisciplinary scientific approaches to critical studies of language as a social practice" (Ramalho & Resende, 2011, p. 12).

Results

The research carried out demonstrated that, when subjected to a methodology in which asymmetrical power relations were controlled, more original and better-selected responses emerged (Carvalho, 2019). Therefore, there was a positive change in the quality of the solutions presented, which can be seen in the significant increase in the originality scores of these solutions (see Table 1) and the strengthening of the levels of participation and interaction that can be seen in the responses to the items collected during the application of the tests and in the speeches that reflect the students' perceptions.

In this work, we will characterize how the interactive processes took place during the activity mediated by the researcher, a situation that allowed for the improvement of collective work, and results that can help teachers and researchers to create expertise that allows them to manage classrooms in favor of developing more active, creative and critical ways of learning mathematics, establishing more democratic interactive patterns (Carvalho & Gontijo, 2020).

Table 1 - Fluency, Flexibility, and Originality scores for the three versions of the TCM

	FluTotal			FleTotal			OriTotal		
	Ver1	Ver2	Ver3	Ver1	Ver2	Ver3	Ver1	Ver2	Ver3
G1	0,56	0,83	0,80	0,59	0,92	0,92	0,23	0,39	0,53
G2	0,47	0,65	0,50	0,53	0,62	0,64	0,19	0,42	0,60
G3	0,45	0,63	0,67	0,56	0,63	0,57	0,22	0,41	0,59
G4	0,52	0,70	0,57	0,63	0,77	0,80	0,35	0,38	0,61
G5	0,63	1,00	1,00	0,70	1,00	1,00	0,28	0,36	0,67
G6	0,54	0,62	0,55	0,63	0,73	0,58	0,29	0,53	0,55
G7	0,51	0,60	0,48	0,58	0,63	0,57	0,32	0,51	0,87
G8	0,72	0,89	0,83	0,64	0,73	0,76	0,31	0,32	0,59
$\bar{x}$	0,55	0,74	0,67	0,61	0,75	0,73	0,27	0,41	0,62
DP	0,09	0,15	0,18	0,05	0,14	0,17	0,05	0,07	0,11

Source: Carvalho (2019).

We will present six characteristics of communicative interactions favorable to the emergence of shared creativity in mathematics and made possible by teacher mediation that

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emerged from the categorization process carried out using the DCA. Elsewhere (Carvalho & Gontijo, 2020; Carvalho, Gontijo & Fonseca, 2020) we have contrasted this positive data with barriers and situations that do not favor collective work based on dialogicity.

The ADC showed us that the work, during the investigation phases, can be classified into three main categories: a) based on dialogic conversation; b) power asymmetry, and c) the actions of distracting subjects. In the first case, high levels of creative sharing were possible as a result of interaction patterns based on dialogic. In the second case, there were exercises of power that prevented everyone from expressing themselves creatively. Finally, in the third case, team members were busy carrying out other actions, hindering the production of ideas.

In Figure 6, we can see the categorization of the characteristics present in the work of teams that, when subjected to teacher mediation through CCM, were able to establish interactions based on dialogic conversation (Diez-Palomar, 2017), which is the focus of this text. According to the author, dialogic conversation refers to discursive interactions in which participants use valid statements to justify their responses, as opposed to non-dialogic conversation which is based on power arguments issued by someone who is using their position of "power" to justify their statements. In the following, we will explore information about these characteristics, accompanied by examples of moments of established interactions.

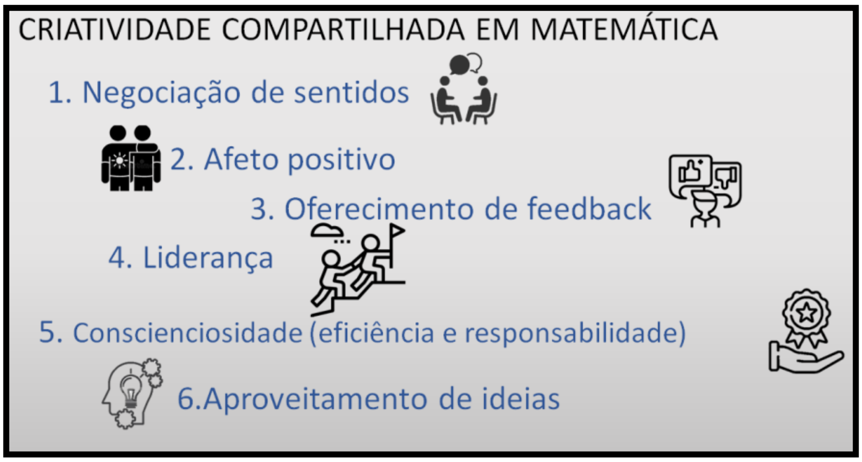

Figure 6 - Characteristics of Shared Creativity in Mathematics
Source: First author of this paper

Negotiating meanings

For Brunner (2001), the externalization of meanings guarantees human participation in the culture they construct, which happens through the sharing and negotiation of meanings: "Although meanings are 'in the mind', they have their origins and their importance in the culture in which they are created. It is this cultural location of meanings that guarantees their negotiability and, ultimately, their communicability" (p. 16). In this investigation, it can be seen that the moments of negotiation of meanings allowed for the improvement of the solutions presented and the installation of interactive patterns aimed at dialogic (Assis, Frade

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& Godino, 2013).

Through arguments of validity, a working group can negotiate the proposed solutions, being able to unite ideas and elaborate them in search of improvement. In addition, the negotiation of meanings allows for the institution of actions guided by plausibility (Lithner, 2008), which can allow for a conscious choice of mathematically true ideas. The research showed that by not negotiating, either through passive acceptance of imposed ideas or through consensus in which there was a lack of reflection on the proposed solutions, the teams compiled erroneous or trivial ideas. With this attitude, they began to rely on their talents, running the risk of making mistakes.

Figure 7 shows the production of solutions by a group that worked through a pattern of interaction with a lack of negotiation, accepting answers that did not respect the criteria stipulated in the question. Of the 10 solutions presented, only five were valid. The group limited the possibilities for solutions, presenting a few categories of answers and ideas with little originality. It should be noted that one of the causes of the difficulty in negotiating ideas stemmed from the fear of presenting the wrong ideas and being judged by the group, which was a factor in limiting access to the speeches made during the collective work, as can be seen in the dialogue between the researcher and a participant in this group (the student had a history of fear of mathematics, and had even undergone psychological counseling as a result of this phobia):

Researcher: Was there anyone in your group who had difficulty in math and you didn't help?
F6: Me.
Researcher: You didn't help?
F6: I helped a little.
Researcher: But do you think you should have helped more?
F6: Yes. I thought I was wrong.
Researcher: And what stopped you from helping?
F6: Because I'm not good at math, so I left... I hardly spoke.
Researcher: And why didn't you speak?
F6: I thought I was wrong, so I didn't want to speak.

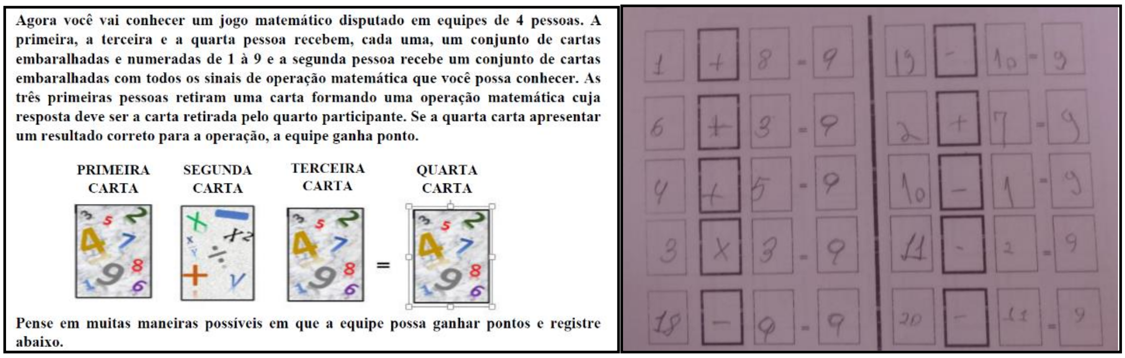

Figure 7 - Productions without negotiation
Source: First author of this paper

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On the other hand, in situations where the participants were willing to negotiate their ideas and defend their points of view, the solutions were refined and could be improved and elaborated together. In another group, student M7 rated all of F11's solutions as wrong. When he received the sheet back, the girl found the correction strange and asked the boy why he had put all the answers wrong. They then had the following conversation:

F11: *Why is it wrong if you can work it out?*
M7: *It's because I didn't understand your handwriting.*
F11: *Wow, you should have just asked me to read it.*

The girl then offers to read each item produced and the boy realizes that the problems created by F11 were correct. The moment of negotiation, in this sense, was important in that it allowed the girl's ideas not to be wasted simply because her handwriting wasn't legible to M7.

Positive Affect

By establishing quality interactions, positive affectionate relationships are created that allow for mutual support and, in this way, the components end up creating a favorable climate for creative sharing. When the opposite happens, people end up creating what Alencar and Fleith (2003) call emotional barriers, producing anticipated criticism and a negative conception of themselves, which, in the research, appears as a negative evaluation that some teams made of the work developed. Guastello believes that "high-quality interaction is characterized by four principles - loyalty, respect, contribution, and positive affection" (Guastello, 2007, p. 7). In these groups, we can see the presence of elements that are characterized by high-quality interaction. For example, when asked what allowed his team to succeed, M2 referred to the unity and appreciation of his colleagues' ideas:

Researcher*: What does a group need to do a good job?*
M2*: The unity of the group, right, friendship, no one fighting with each other and no one, like, leaving each other's ideas behind because they think their idea is better.*

The teams that managed to develop high-quality interactions, mediated by the teaching action, were able to establish positive affective relationships, based on respect and politeness in their treatment of others, finding "the comfort and trust necessary for creativity" (Mumford & Gustafson, 1988; Boaler, 2018). On the other hand, in teams that fail to build positive affection, there is a feeling of failure and repression of the expression of ideas (Carvalho, 2019).

The teacher has an important role to play in establishing relationships based on positive affection since when students feel respected, integrated into the group, welcomed, and valued, they begin to feel authorized and able to explore the mathematical environment (Boaler, 2018), to demonstrate "a willingness to take intellectual risks" (Beghetto, 2010, p. 458), "share new ideas and insights, raise new questions and try to do and experience new things" (Beghetto, 2010, p. 458).

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Offering feedback

By mediating conflicts and asymmetrical power relations, the researcher allowed students to evaluate their colleagues' solutions, pointing out mistakes and suggesting improvements. This finding is in line with studies in the field of leadership which indicate that more creative solutions can be obtained when the people involved in the creative action provide appropriate criticism or evaluation (Guo, Dilley & Gonzales, 2016).

When asked what she thought about carrying out the activity in the version with mediation, student F7 showed how important the provision of feedback proved to be for collective work, providing criticism that allowed the solutions to be improved.

F7: *It was better than the other times.*
Researcher: *Why?*
F7: *Because when we do it alone, people don't criticize. And then when we show them the idea and explain it, they understand.*

The same understanding was presented by another child, who demonstrated the importance of criticism as a way of providing feedback:

Researcher: *How did your team do?*
M7: *We did better than the second time. One person was helping the other and it wasn't like the first time. The first time they didn't help each other, they didn't criticize each other to improve the ideas.*

It should be noted that the process of providing feedback allowed for the installation of a complex network of interactions characterized by the variety and quantity of conversational behaviors, such as asking questions, offering creative ideas, expanding on the ideas of others, facilitating the expression of others, etc. (Guastello, 2007), which meant that contributions were valued and improved.

Bezerra, Gontijo, and Fonseca (2021) discussed the potential of using feedback to stimulate creativity. At the time, they proposed the terminology "creative feedback", referring to feedback whose purpose is to develop the individual's creative potential. Although the authors did not go into the discussion of the actors who offer and receive creative feedback, it is possible to deduce from the findings of this research that, in addition to the possibility between teacher and student, this type of feedback can be constructed and offered by peers - it is up to the teacher to nurture the classroom climate for healthy and constructive cooperation between students.

Leadership

In our studies (Carvalho, 2019; Gontijo & Fonseca 2020) we have noticed that groups in which leadership emerges, directing collective work, have obtained high creativity scores in mathematics, demonstrating many, varied, and original ideas. By coordinating the work of the team, these leaders have managed to raise the motivation level of the members and get

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everyone involved in the task, allowing them to concentrate on the activity and make the most of the time available to dedicate to producing solutions. Bearing in mind that the level of enthusiasm for the activity is a necessary component of intrinsic motivation (Tierney, Farmer & Graen, 1999), these groups turned out to be highly motivated.

Figure 8 shows this process of creative production coordinated by the leaders, which was characterized by the multiplicative nature of creativity (Mitchell, Glaveanu & Reiter-Palmon, 2017) in which the action of a leader, validated by the other members, managed to boost the creative activity of his team. This was possible because the leader coordinated the team's work, leading them to install a high flow of information (with correct and other mistaken ideas), guided by democratic dialog. In turn, democratic dialogue allowed the team to come up with many solutions (starting with individual production), recognize good ideas (blind evaluation), combine them (negotiation and compilation), and collectively build flexible and unusual solutions (throughout the process).

As a result, they were able to improve the quality of their teamwork, allowing the production of ideas to be guided by democratic decision-making. In this step, ideas generated by both the leader and the others were worked on with everyone's collaboration, with the leaders playing an organizational role in this dynamic, boosting the creativity of the others.

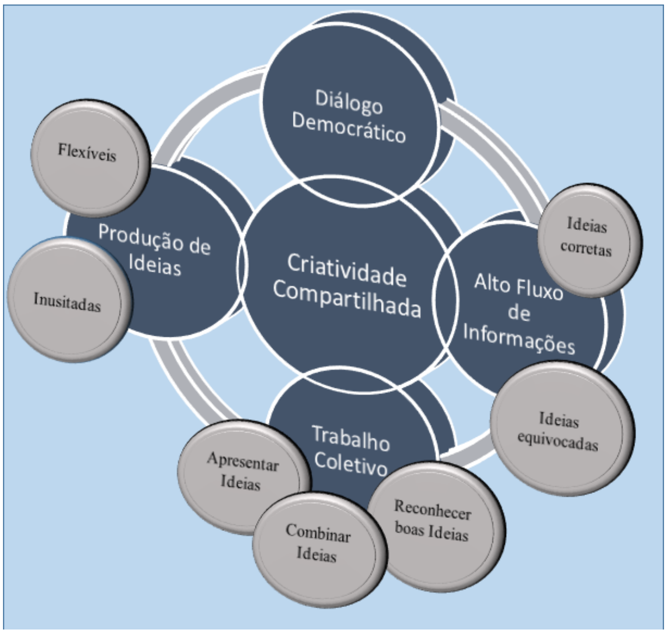

Figure 8 - Creative Sharing process coordinated by the leadership
Source: Carvalho (2019).

Four teams showed the emergence of leaders after the mediation was carried out. Members who had previously been seen as distractors or dominators, receiving a lot of criticism from their peers, became important subjects for the collective work.

As a leader, M16 was important in providing important feedback for the conscientious selection of solutions and the improvement of mistakes. For example, in Figure 9, you can

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see that, after the round of corrections, the children began to check their solutions and F2 asked why his first two answers were wrong. M16 read the wording of the question to the girl, who soon realized that she had made a mistake because she had used numerals above six.

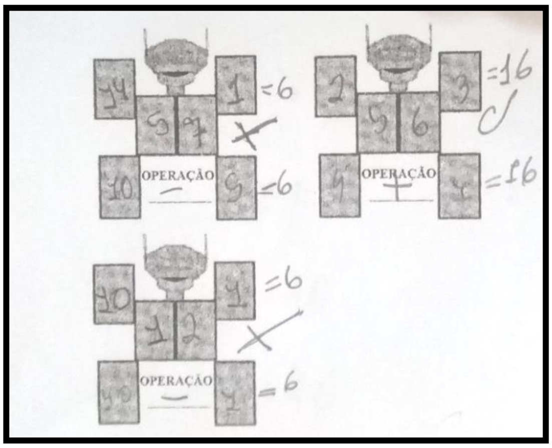

Figure 9 - Improvement of solutions coordinated by leadership
Source: Carvalho (2019).

He then asked the girl to try and come up with another answer, using the correct rules. F2 realized that it would be difficult to find a subtraction solution, so he started thinking about addition, arriving at the correct solution shown in Figure 9.

Conscientiousness

This characteristic refers to the careful choice of solutions that are appropriate to the rules and restrictions imposed during the creative action. It can be seen that by being conscientious, teams sought to critically evaluate the solutions presented, putting them to the test to ascertain their suitability. According to Amabile (1996), for a product or response to be considered creative, it is not enough for it to be new; it also needs to be appropriate or useful. Therefore, conscientiousness allows teams to choose solutions that can meet the established criteria.

We can illustrate how this characteristic influenced the creative process by giving the example of the group formed by F1, F2, and M2. After evaluating the individually produced solutions, in which each answer was carefully analyzed by the participants, the boys went on to comment on the idea illustrated in Figure 10 (F1's original idea). They thought the solution

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was fantastic and different from the team's productions. However, they had doubts about whether the answer was correct since they weren't sure if each color took up the same amount of space.

F2 then went on to explain how he thought of the idea, saying that he first divided the rectangle into 6 pieces with vertical lines. In this way, he demonstrated that the two pieces at the end occupy the same amount of space as the other parts. He then said that he would like to use other types of lines to make the answer different from the others. So he used the vertical lines in the center of the rectangle, tilting them. Figure 10 illustrates how the girl reasoned to come up with the idea that caught the team's attention.

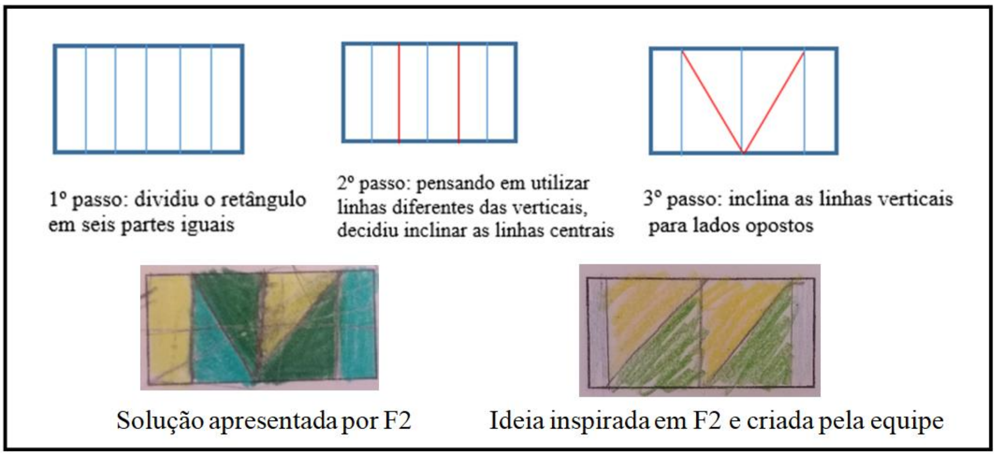

Figure 10 - Productions without negotiation
Source: First author of this paper

The boys were convinced by their colleague that the idea was correct and, because they found it very original, they started to try another solution using the same reasoning. With everyone's participation, they gradually thought of a way to come up with a different answer to the one presented by F2, but using the same principle. They then negotiated and decided to use two diagonal lines pointing to the same side, producing two solutions that no other group had thought of. By putting conscientiousness into action, the team carefully evaluated the ideas proposed, which also allowed the whole group to be inspired, presenting an excellent creative performance (see Table 1 for the results presented by Group 5).

Making the most of ideas

We chose the example of F6, who had a history of being afraid of math, to illustrate the importance of the moment of harnessing ideas that took place in several groups. This group was able to create a very intense process of interaction, in which all the group members were involved and participative. This allowed student F6 to gain confidence and contribute to the development of ideas.

When she presented ideas, even if they were wrong, her peers discussed them and, instead of rejecting them, tried to make the most of them, showing F6 that her contributions

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were welcome and important for the group's performance. Figure 11 shows how M10 tried to take advantage of F6's idea, which at first was incomplete because it didn't have a question to answer. The boy told his colleague that the idea of using information about people sitting and people standing was very good and hadn't been thought of by the others. When the team was compiling the solutions on the answer sheet, M10 suggested that they use the information remembered by F6. In this way, everyone arrived at a valid solution.

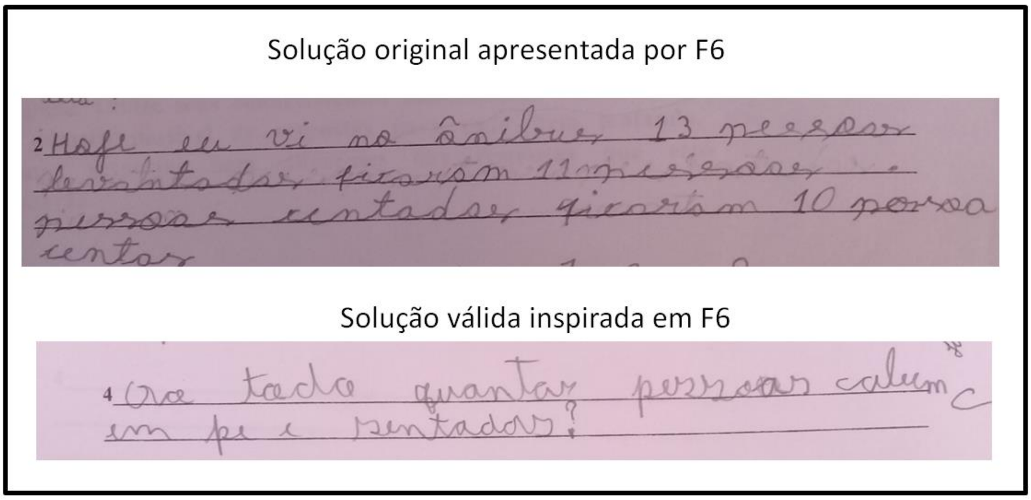

Figure 11 - Making the most of ideas
Source: First author of this paper

This result indicates that, when mediating interactions in the classroom, teachers need to focus on critical work to allow students to establish patterns of interaction aimed at carefully and respectfully evaluating the ideas of their peers. In the context of collective work mediated by the researcher, harnessing ideas allowed everyone to feel like a protagonist in the search for solutions to problems. For student F6, the acceptance of her ideas was an important step towards overcoming her trauma with mathematics.

Some excerpts from the participants' speeches illustrate the importance of harnessing ideas for the collective construction of mathematical solutions, as described below:

Researcher: *What made the team successful?*
M10: *We talked about the ideas and didn't waste the ones that didn't work out.*

M15: *At first you didn't develop your ideas. Because there were his ideas and two other people putting in theirs, it was better for everyone to come up with their ideas and exchange them with the others.*

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The characteristics of Creative Sharing shown here indicate that the teacher has an important and indispensable role in the classroom by curbing interactions that hinder everyone's participation.

Conclusions

As Beghetto (2010) points out, the school experience has removed the possibility of nurturing creative potential from the academic curriculum. It is the teacher's job to allow classroom interactions to favor the democratic exchange of ideas in search of the collective construction of knowledge. As Siriraman (2004) believes, in the creative process of mathematicians, social interaction is an important element for creative work, especially in the preparation stage. For some time now, we have been searching for alternatives to overcome the failed traditional teaching methodologies, which focus on reproduction. Attempts to build dialogic, interactive spaces that allow for collective work have shown promise in that they allow for the exchange of experiences and the improvement of mathematical reasoning strategies.

Today's students "develop their meaning of mathematical ideas through a process of interaction and communication in the classroom" (Guerreiro et al., 2015, p. 16). The interactions instituted in the classroom must allow everyone to feel authorized and capable of reflecting mathematically, constructing ideas, and improving them in collective activity with their peers. This study showed that students were able to create collective solutions to mathematical problems, leading the work through negotiation of meanings, positive affection, offering feedback, leadership, and conscientiousness in the selection of ideas. Shared creativity in mathematics, therefore, is a process that, once established in the classroom, will help teachers and students to experience rich moments of exchange and negotiation of meanings.

In our research, the role of the teacher proved to be fundamental in establishing communicative interactions based on respect for others, negotiation of meanings, and other processes that made it possible to improve moments of sharing ideas and, consequently, good results in terms of creativity.

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