ACTA SCIENTIAE
ISSN: 2178-7727
DOI: 10.17648/acta.scientiae.6213

Fostering Mathematical Creativity in the Classroom through Feedbacks

Wescley Well Vicente Bezerra [a]
Cleyton Hércules Gontijo [b]
Mateus Gianni Fonseca [c]

[a] Universidade de Brasília, Faculdade UnB Planaltina, Brasília, DF, Brazil.
[b] Universidade de Brasília, Programa de Pós-graduação em Educação da UnB, Departamento de Matemática da UnB, Brasília, DF, Brazil.
[c] Instituto Federal de Educação, Ciência e Tecnologia de Brasília, Campus Ceilândia, Brasília, DF, Brazil.

Received for publication 21 Oct. 2020. Accepted after review 12 Mar. 2020
Designated editor: Claudia Lisete Oliveira Groenwald

ABSTRACT

Background: Given the importance of stimulating the creative potential of students in the classroom, it is relevant to investigate how the assessment of learning, especially the use of feedbacks, can contribute to this issue**. Objectives**: This article aims to discuss what characterises creative feedback in the mathematics field and illustrates this characterisation by reporting a pedagogical practice carried out with students attending the last year of high school in a Brazilian public school. **Design**: Qualitative analysis of reports of students who participated in a pedagogical activity. **Settings and participants**: Four students enrolled in the 3rd grade of high school integrated with professional education in a public educational institution in the Brazilian capital. The students participated voluntarily after an invitation to the institution. **Data collection and analysis**: The data was collected from recordings of video calls through Google Meet platform and students' written production through WhatsApp instant messaging application. **Results**: The messages exchanged between the teacher and the students revealed that the feedback focused on developing creativity enabled them to create different and innovative ideas. **Conclusions:** Creative feedback proved to be an important concept to stimulate students' mathematical creativity. We suggest research on critical thinking development through creative feedback and creative peer feedback for further investigations.

Keywords: Creativity in mathematics; Formative assessment; Creative feedback ; Problem solving.

Corresponding author: Wescley Well Vicente Bezerra. Email: wescley@unb.br

Promovendo a Criatividade em Matemática em Sala de Aula por Meio de *Feedbacks*

RESUMO

Contexto: Dada a importância de se estimular o potencial criativo dos estudantes em sala de aula, é relevante investigar de que maneira a avaliação da aprendizagem, em particular, a utilização de *feedback*s, pode contribuir para essa questão**. Objetivos**: O objetivo do presente artigo é fazer uma discussão acerca do que caracteriza um *feedback* criativo no campo da matemática e ilustrar essa caracterização por meio do relato de uma prática pedagógica realizada com estudantes do último ano do ensino médio de uma escola pública brasileira. **Design**: Análise qualitativa de relatos de estudantes que participaram da de uma atividade pedagógica. **Ambiente e participantes**: Quatro estudantes, todos matriculados no 3º ano do ensino médio integrado com uma formação profissional, em uma instituição pública de ensino da capital brasileira. A participação dos estudantes foi voluntária, a partir de um convite realizado à instituição. **Coleta e análise de dados**: A coleta de dados foi realizada por meio da gravação de videochamadas, por meio do uso da plataforma *Google Meet,* e do registro escrito da produção dos estudantes, por meio do aplicativo de troca de mensagens instantâneas *WhatsApp* **Resultados**: A partir das mensagens trocadas entre professor e alunos, ficou evidente que o *feedback* voltado para o desenvolvimento da criatividade possibilitou aos alunos a criação de ideias diferentes e inovadoras. **Conclusões:** O *feedback* criativo mostrou ser um conceito importante para estimular a criatividade matemática dos estudantes. Para futuras investigações, propõe-se a investigação do desenvolvimento do pensamento crítico por meio dos *feedbacks* criativos, bem como do *feedback* criativo entre pares.

Palavras-chave: Criatividade em matemática; Avaliação formativa; *Feedback* criativo; Resolução de problemas.

INTRODUCTION

The complexity of modern life and the challenges for sustainable and inclusive development require new skills to treat contemporary problems properly. One of these skills stands out: creativity. According to the World Economic Forum (WEF, 2018), creativity was considered the third most important skill in the labour market in 2020, second to complex problem solving and critical thinking skills.

Besides creativity, the development of adaptability becomes relevant today, as machines evolve more and more. Regarding adaptations, they tend to require a higher level of education or more time for activities that require social and emotional skills, creativity, high-level cognitive abilities, and other skills that are relatively difficult to automate, i.e., the "demand for higher cognitive skills will grow moderately overall, but will rise sharply for some of these skills, especially creativity" (Bughin et al., 2018, p. 4). To meet this demand, Manyika et al. (2017) recommend that policymakers work with those responsible for education systems "to improve basic skills through the schools system and put a new emphasis on capabilities that are among the most difficult to automate, including creativity, understanding human emotions, and managing and coaching others" (p. 113).

According to Gonçalves, Fleith, and Libório (2011, p. 23), the creative potential has been little stimulated in the school context, indicating that "schools have in fact resisted working on the development of curricular components in an articulated manner with strategies to stimulate students' creativity and motivation to learn."

A recent initiative in the educational landscape was developed by the Organization for Economic Cooperation and Development (OECD), releasing the article "Fostering students' creativity and critical thinking: what it means in school" (Vincent-Lancrin et al., 2019), highlighting the role of school in the development of students' creativity and critical thinking. According to Vincent-Lancrin et al. (2019, p. 13),

> with artificial intelligence and robotics possibly leading to automation prospects for a sizeable share of the economy, skills that are less easy to automate such as creativity and critical thinking become more valued. Even if there was no economic argument, creativity and critical thinking contribute to human well-being and to the good functioning of democratic societies.

This OECD publication arises when large-scale assessments developed by international bodies are being changed, while tests that measure skills in curricular components such as mother tongue, mathematics and science begin to include other non-academic skills in their instruments. In this context, we highlight the OECD's Programme for International Student Assessment (PISA), which will assess creative thinking skills in a test scheduled for 2021. The inclusion of creative thinking assessment in the PISA test will undoubtedly impact the curriculum policies of member countries and OECD members participating in this assessment programme, leading governments to encourage, identify, and fund innovative educational programmes aimed at stimulating complex problem solving skills, critical thinking, and creativity, besides disseminating such programmes to meet PISA's demands. The stimulus to the development of those skills should be treated as an educational right aimed at the students' full development, contributing to achieving the national education goals, recommended in the Law of Directives and Basis for National Education (LDB) - Law No. 9.394 of December 20, 1996.

Research and debates about creativity are not recent. Since the 1950s, an increasing number of studies have been emerging in this area, such as the works of Guilford (1950), references that still form the basis of many investigations today. In recent decades, some theories have gained prominence due to the systemic approach used to study the complex phenomenon of creativity, associating it with social processes and the contexts in which individuals and products or ideas are created. Among the theories that fall within this approach, we cite the investment theory of creativity (Sternberg & Lubart, 1991, 1993, 1995, 1996), the componential model of creativity (Amabile, 1983, 1996) and systems perspective of creativity (Csikszentmihalyi, 1996, 1999). Sternberg and Lubart, in their investment theory of creativity (1991, 1993, 1995, 1996), identified the intelligence, intellectual styles, knowledge, personality, motivation and the environmental context as relevant for the development of creative expression. In the componential model of creativity proposed by Amabile (1983, 1989, 1996), domain, relevant creative processes and intrinsic motivation skills, besides the environment, are considered necessary for the development of creativity. In Csikszentmihalyi's systems perspective (1996, 1999), creativity occurs as a process of dialectical interaction between three systems: individual, domain, and field.

A common element between these theoretical models and other approaches to creativity is a certain consensus about what characterises creativity. This consensus is considered as the result of the interaction between skill, process, and environment, through which an individual, or a group of individuals, produces something that is considered innovative and useful within a given social context (Plucker, Beghetto & Dow, 2004). In this sense, usefulness and novelty predominate in the conceptions of creativity.

Based on this concept, we consider it valuable to highlight another model for the study of creativity, developed by Kaufman and Beghetto (2009), known as the four-C model of creativity. The authors emphasise that most investigations on creativity tend to take one of two directions: to study everyday creativity (called little-c), which can be found in almost all people, and eminent creativity (called Big-C), found in people with great projection in a field of knowledge due to the impact of their works on society. By proposing the four-C model of creativity, the authors seek to break with this dichotomy by adding the idea of mini-c, creativity inherent to the learning process, and the idea of Pro-c, which is the progression of development and effort beyond little-c, representing the professional level experience in any creative area. Thus, creativity could be observed from a more elementary level to a level that represents great creations - mini-c, little-c, Pro-c, and Big-C.

Taking Kaufman and Beghetto's (2009) model to discuss creativity in the school environment, we highlight the importance of developing a pedagogical work that includes strategies to stimulate students and adopting formative assessment practices. Motivated by the specialised literature and the need to foster creativity in school, especially in mathematics, we proposed using a strategy for the classroom.

In this sense, this article aims to discuss what characterises creative feedback in the mathematics field and illustrates this characterisation by reporting a pedagogical practice carried out with students attending the last grade of high school of a public school located in Brasília, FD, Brazil. Therefore, in this work, we will highlight the potential of formative assessment to stimulate creativity in mathematics, since one of the main characteristics of this evaluation is to provide students with feedback.

THEORETICAL FRAMEWORK

Although there is a consensus on the need to foster creativity in the classroom, there are still difficulties implementing it as part of curricular activities. Among these difficulties is the lack of clarity about what characterises creativity in the mathematics field, how to encourage it, and how to assess this type of thinking ability. Fostering creativity in mathematics classes would not mean ignoring the acquisition of skills or accessing, processing, and retaining mathematical information, but involving the use of creativity to enhance learning (Gontijo, Carvalho, Fonseca, & Farias, 2019).

We agree with Gontijo (2007, p. 37), who describes creativity in mathematics as

> the ability to present numerous suitable potential solutions to a problem situation, so that they focus on distinct aspects of the problem and/or differentiated ways of solving it, especially unusual forms (originality), both in situations that require the problem solving and problem posing and in situations that require the classification or organisation of objects and/or

> mathematical elements according to their properties and attributes, whether textually, numerically, graphically, or in the form of a sequence of actions.
>
> This idea applies both to empirical research, focused on the investigation of students' creativity, and to the development of practical activities in the daily life of mathematics classes in the school environment, as it puts in evidence three dimensions that allow its operationalisation: expression of creative thinking (fluency, flexibility, and originality), strategies to stimulate creativity (problem solving, problem development, and redefinition) and forms of expression of creative thinking (textual, numerical, graphical production, or sequence of actions).

The different instruments used for students to express their thinking constitute rich analytical material. Through them, teachers and students can establish a communicative process that favours the development of creativity and learning in mathematics. We call this communicative process, which is part of the formative assessment, *feedback*.

According to Brookhart (2008, p.1), formative assessment provides information to teachers and students about how they are evolving according to the learning goals. Moreover, the author points out some essential characteristics of the formative feedback that are related to 1) the feedback strategies: time (when and how often should it be given), quantity, mode (oral, written, or visual), audience (in groups or individually); and 2) the content of the feedback: focus (on the work, on the process, on self-regulation, or the student's personality), comparison (compare with criteria for a good job, or with other students, or with the student's past performance), function (description or assessment), valence (positive or negative), clarity, specificity, and tone (Brookhart, 2008).

According to Zhou (2008), contemporary research in the organisational landscape has shown that feedback can have a powerful impact on individuals' creative performance. From this, we emphasise that feedback can also be related to fostering creativity in the classroom: by receiving a return on their learning, students can develop self-perception of their creative capacity and feel encouraged to present their spontaneous concepts and alternative algorithms, which also contributes to the development of their creative potential.

We define feedback intended to develop creative potential as creative feedback. We understand that besides the particularities of effective formative feedback, the following are characteristics of the creative feedback: 1) stimulate the development of creative thinking skills, such as fluency, flexibility, and originality, and analysis and judgment of one's ideas; 2) promote the development of self-perception of creative capacity; and 3) boost or maintain intrinsic motivation.

Creative thinking skills, fluency, flexibility, and originality are widely used in tests aimed at assessing creativity. According to Gontijo, Carvalho, Fonseca, and Farias (2019, p. 81),

> a) fluency: represents the number of different ideas generated and that configure suitable solutions to the problems proposed;
>
> b) flexibility: refers to the number of different categories in which the solutions generated for each problem can be classified;
>
> c) originality: corresponds to the infrequency or non-conventionality of the ideas generated, that is, suitable solutions that differ from the large group of solutions proposed are considered original.

We understand that through creative feedback, the teacher can stimulate the development of different ideas for the students' solutions. Thus, by presenting different answers to the problems resolved in the classroom, students can feel confident to socialise different solutions to the questions proposed, and to present their spontaneous concepts and their schemes during the solution (Vergnaud, 1993). In this way, creative feedback will contribute to fluency and flexibility, which are crucial creative thinking skills.

By using creative feedback, the teacher can support the development of their students' mini-c creativity. This is because once encouraged to present their different solutions, the students can develop new ideas for themselves, even if this does not represent something new for students' collective. Thus, originality will be related to the interpersonal character, being a subject's set of new valuable ideas without necessarily being original to other people.

The development of creativity involves deconstructing the conceptions that this ability is a special gift or comes from deities and is restricted only to geniuses. Thus, feedback that values students' productions as original (in the sense of mini-c creativity) can favour students' self-perception of creativity, making them see themselves as beings capable of generating new ideas and solutions to the problems presented in the classroom and encouraging them to produce more and more original solutions and feel confident with their abilities.

Although it seems to be an inherent characteristic, intrinsic motivation can be fostered in the classroom. Alencar and Fleith (2003, p. 5) state: "although it can be considered, in part, innate, intrinsic motivation can be cultivated, on a large scale, by the social environment". Thus, it is essential to provide feedback that can stimulate the students' interest in the tasks, making them increasingly involved, challenging them, and contributing to their intrinsic motivation. Consequently, we understand that this creative feedback can drive student creative performance.

Research has shown that motivation in relation to mathematics seems to be a decisive element for students to allow themselves to risk unusual, creative ideas (Grégoire, 2016, Kanhai & Singh, 2017). This argument is corroborated by other research in creativity in mathematics, for example, Petrovici and Havâmeanu (2015) and Gontijo (2007). According to those authors, creative feedback can be a critical motivational resource and stimulate students' creativity.

We can observe that, in developing creativity, there is an intense relationship between individual and social factors. As the development of creative potential is a major challenge for schools in the 21st century, as much as challenging is the adoption of formative evaluation in a context marked by large-scale assessment models, developing a culture of creative feedback can be an alternative to building new ways of experiencing schooling processes, giving sense and meaning to school action and favouring the development of creative thinking.

METHODOLOGY

The research was developed from the perspective of the qualitative research approach (Minayo, 2002), which has been used in many investigations in mathematics education aimed at analysing the processes of teaching and learning. Qualitative research, from the perspective of Garnica (2004), is characterised by:

> (a) [...] transience of its results; (b) [...] impossibility of an a priori hypothesis, whose objective of the research will be to prove or refute; (c) [...] non-neutrality of the researcher who, in

> the interpretative process, uses his/her previous experiential perspectives and filters from which he/she cannot get rid; (d) [...] constitution of his/her understandings [...] as a result, but in a trajectory in which these same understandings and also the means of obtaining them can be (re) configured; and (e) [...] impossibility of establishing regulations in systematic, prior, static, and generalist procedures (p. 86).

Considering the characteristics pointed out by Garnica (2004), there is an identification between the qualitative approach and our study, since

> (a) the process of students production of solutions to mathematical problems, from creative feedback, does not have a defined point of arrival, since students can at all times resume their activity, moving between ideas and constructions, and the final product is determined by them and not by the teacher or by a temporal demarcation;
>
> (b) this is an investigation in the field of creativity, students are expected to present solutions that escape the models routinely found in the classroom, which a priori prevents indicating patterns of responses and behaviours expected from students;
>
> (c) from the perspective of creative feedback, researcher and students are active in the information production process, acting both interactively and dialogically, which signals the impossibility of neutrality throughout the process;
>
> (d) the process of students' mathematical production throughout the activity will be guided and self-regulated by them, and this process and the forms of communication between peers and with the researcher can be changed if convenient;
>
> (e) the study presented here is circumscribed in a certain context, and the interpretations of the results relate only to the conditions under which the activity was developed.

Another important aspect of this research is its exploratory character (Gil, 2008), as the theme investigated, creative feedback in mathematics, is still little known and explored in the field of mathematics education and, in this sense, the procedures adopted are new, without parameters to compare with other research from the theoretical and the methodological perspective. This aspect justifies the non-presentation of possible expectations concerning the students' production, whose analyses may provide future studies and allow inferences when analysing similar experiences.

Participants

The activity described in this research was carried out with four students designated by letters A, B, C, and D to preserve their identities, all 17 years old, enrolled in the 3rd grade of high school integrated with professional qualification, in a public educational institution in the capital of the country. The students accepted to participate voluntarily, after an invitation we made to a group from one of the classes of the institution. The institution was chosen because one of the researchers works there, which favoured contact with the school's management and teachers. The researchers were not the official teachers of the classes the students were enrolled and had had no previous contact with the participants. Students agreed to participate in the research by signing an Informed Consent Form (ICF). Students' adherence occurred during the suspension of classes imposed by the Covid-19 pandemic, and they were longing for an opportunity to prepare for the National High School Exam (ENEM). Thus, for the students, participating in the research was a convenient choice.

The exploratory nature of the research, which sought to characterise creative feedback and develop a practical activity in mathematics based on this characterisation, requires a reduced number of participants so that it is possible to ensure careful monitoring of the productions and problematisation and feedback in an appropriate manner.

Procedures

Due to the social distancing guidelines and the suspension of face-to-face activities in the educational institution surveyed due to the Covid-19 pandemic, data were collected through video calls, by Google Meet platform, and the instant messaging application, WhatsApp. The video call served to introduce each stage of the activity and for the teacher/researcher who conducted the activity to make general considerations and provide students with collective feedback. The WhatsApp app was used as an individualised space for creating answers and for individual feedback. The activities described here were developed in a meeting that lasted about one hour and thirty minutes.

According to what Brookhart (2008) defends about feedback, in this activity, the continuous exchange of messages during task execution was adopted as a strategy, in a written (individual) way, by the messaging app, and orally (collective) by video call. We highlight that the focus shifted between the result presented, the process used and the stimulus to self-regulation. We strove for clarity of language, specificity of comments, and cordiality in communication during the messages – always searching to encourage students to think, without necessarily resorting to direct instruction, in a friendly tone.

Also, the activity applied is characterised by the creative feedback, i.e., we tried to stimulate the development of the students' creative thinking skills, such as fluency, flexibility, and originality, fostering self-perception of creative capacity, boosting, or maintaining intrinsic motivation. Finally, the data analysis was based on the students' written production forwarded by the messaging app and the video calls records.

The activity developed

Among the various types of mathematical activities that can be developed with students, those with the greatest potential to stimulate creativity are those that include open-ended problems, because the problems enable the creation of many forms of solution (Gontijo, 2020). In solving open-ended problems, students should be responsible for decision-making, not entrusting this responsibility to the teacher or to rules and models presented in textbooks (Gontijo, 2015). Gontijo (2020, p. 157) points out that

> The decision on the type of method and/or procedure that will be used can be made from students' knowledge and previous experiences, especially those arising from the work already developed to solve similar problems or with which they had contact. We emphasise the need to provide students with the opportunity to build their own models, test them, and then reach the solution. It will also be necessary to build a strategy to communicate to colleagues and the teacher their experience of solving the problem, explaining the mental process used and how they reviewed the strategies selected to arrive at the solution.

Considering the aspects of open-ended problems and the National Common Curricular Base (BNCC) guidelines, we selected a skill related to geometry and measurements to work with the students. It is a skill linked to high school, described in BNCC: “(EM13MAT201) Propose or participate in actions suited for the demands of the region, preferably for its community, involving measurements and calculations of the perimeter, area, volume, capacity, or mass.” Thus, the activity analysed is characterised as an open-ended problem that explores introductory aspects of perimeters and areas.

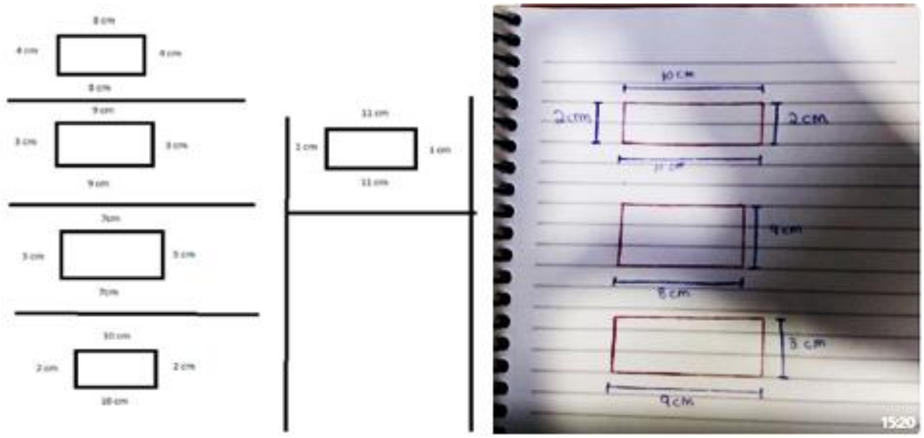
RESULTS AND ANALYSES

In this section, we describe the activity performed. The first problem presented to the students was: *A rectangle has a perimeter of 24 cm. Find as many different rectangles as you can with a perimeter equal to 24 cm.*

For this problem, each student produced a different number of rectangles as solutions. Student A (Figure 1, left) used the computer to perform five representations of rectangles, while student B offered three (Figure 1, right):

Figure 1

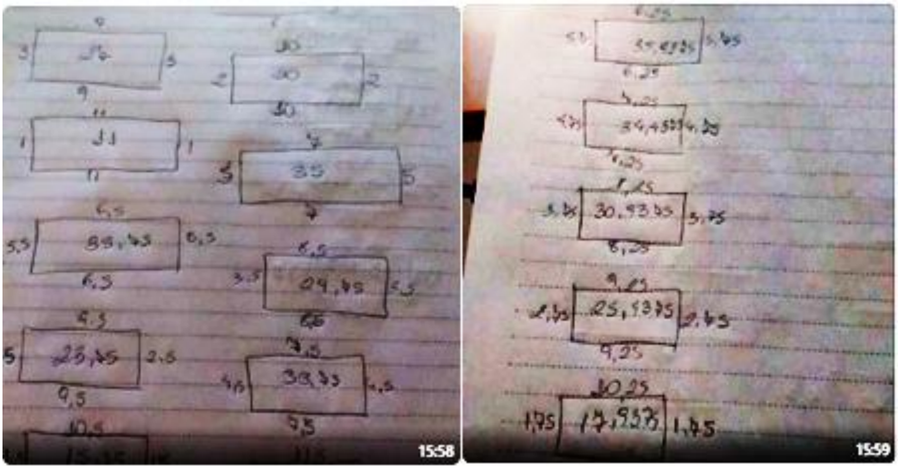
Student A (left) and Student B (right) solutions



Student C was not satisfied with the time allocated for the production of representations of rectangles. Initially, he gave eight answers (Figure 2, left), but after a few minutes, he presented five others (Figure 2, right).

Figure 2

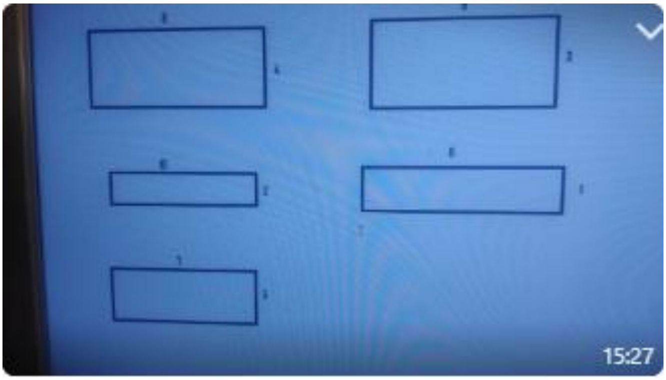
Student C's solutions



Like student A, student D used the computer to construct the representations of their rectangles, proposing five solutions (Figure 3):

Figure 3

Student D's solutions



Observing students' productions, we recall that one of the objectives of the creative feedback is to stimulate the development of creative thinking skills, i.e., stimulate fluency (amount of answers produced), flexibility (different categories of answers), and originality (rare answers among group members) of thinking (Gontijo, Carvalho, Fonseca & Farias, 2019). Although everyone proposed more than one solution, demonstrating fluency of thought, most of such solutions involved only natural numbers, demonstrating low flexibility. In the group conversation with the students, captured by the video call, they agreed that they could have presented more answers involving other types of numbers. Among the four participants, only student C "innovated" by inserting decimal numbers in the measurements.

As noted, another purpose of creative feedback is to promote the self-perception of the creative capacity and boost or maintain intrinsic motivation. We pointed out that the communication processes that occurred during the activity mobilised the students to perform the task, intensifying the intrinsic motivation (Zhou, 2008), which was marked in the production of student C, who surprised us with the number of answers he gave when compared to the other students. In the group conversation, student C revealed that he was determined to produce many solutions, from the perspective of an individual overcoming his limits.

The second problem was: *A rectangle has a perimeter of 24 cm. What might its area be?*

Different answers emerged for this problem, among them: 32 cm² (base 8 cm and height 4 cm), 20 cm² (base 10 cm and height 2 cm), 27 cm² (base 9 cm and height 3 cm) and 33.75 cm² (base 7.5 cm and height 4.5 cm), student C's answer, who, once again, proposed the use of decimal numbers. Asked about the procedure adopted to produce these answers, the students claimed to have "taken advantage" of the drawings built previously, even though they knew they could find other areas, with different extensions.

Until this moment of the activity, the feedback was not used to problematise the numerical set they were using to build their solutions, this reflection was raised more naturally, without inducing the construction with decimal numbers.

The following question was: *do you think that the problem has all the information necessary to calculate the area of a rectangle, since only the measurement of the perimeter was informed, i.e., that the perimeter of the* *rectangle is 24 cm? Could you have additional information to help resolve the issue?*

Student A initially proposed:

> *Maybe so, but I would have to deduct two other numbers from a single one and I don't have enough knowledge to make such a statement.*

The feedback at this time aimed to question whether students lacked the knowledge to solve the problem or if they imagined that there was some information missing that would make it possible to find the solution. After a few minutes, a student reworked his answer, stating that the area results from the product between the base and height of the rectangle and that the perimeter is the sum of the measures that make up this polygon, adding: "*I believe that the values can be infinite, so there is some data missing. You having the answer to one does not imply that you will have the answer to another*."

At this moment, the student is in an internal process of generating ideas, reflecting on the mathematical object in question and analysing the possible solutions that come to mind – it is creative thinking in action, where ideas flow, transiting between models and categories, glimpsing new configurations to present (Gontijo, Carvalho, Fonseca & Farias, 2019). Thus, to further stimulate the process of generating ideas, the teacher asks students if it would be necessary to know, in fact, all the values of the rectangle, and after a few minutes, he said it would not:" *[from] one of those two it is possible to deduce the other and so you can calculate the area*."

Next, two students assertively presented their answers. The first answer is from Student B:

> *No, because the same perimeter may contain different values for the base and height, and when multiplied, they give distinct results [...] the value of some variable of the formula would have to be given in the statement.*

Then, student C states:

> *No. Because there can be several shapes of a rectangle. Several measures that result in a different area [...]. I think that at least one side of the rectangle would be essential*.

In the case of student D, the constant feedback exchanged between teacher and student contributed to the generation of ideas. The student even exchanged answers after reflection raised in the dialogues with the teacher, as can be seen below:

> [Student] : *Yes, since by multiplying the values of the base and the height of this rectangle, we can find the area.*
>
> [Teacher]: *Do these different rectangles you generated have the same area, then?*
>
> [Student]: *No, because their values are different, so, even though they have the same perimeter, their areas will be different.*

And after about a minute, the student resumes:

> [Student]: *Teacher, I want to change my answer. Now I've thought better about the question, I'm sorry.*
>
> [Teacher]: *Easy, you can change as many times as you want.*
>
> [Student]: *In this case, it is not possible to reach a result, because there are several possible areas that we can find with the perimeter. To reach an answer I would put the value of the base or the height.*

After this construction of ideas, the group was asked another question: *what do you notice by comparing the areas of the different rectangles you built? Is there any pattern? Explain it.*

At this point, they were asked to calculate the areas of the different rectangles they had built in the first part of this activity to be able to reflect on this issue. The changes made in the answers after some time of reflection is something interesting and apparent in this set of tasks, and this demonstrates how creative thinking continues in action. The observation of the students' actions suggests that they intuitively produce their answers following the stages of the creative process proposed by Wallas (1926), in a sequence that involves preparation, incubation, *insights*, and verification of ideas. Initially, student A replied:

> [Student]: *8 * 4 = 32*
>
> *9 * 3 = 27*
>
> *7 * 5 = 35*
>
> *10*2= 20*

*11 * 1 = 11*

[Teacher]: *Would you say there is any pattern? Or any logic between those numbers?*

[Student]: *I'm still in the process of analysis. I didn't see any patterns...*

After about 5 minutes, the student resumes:

[Student]: *See:*

*7 * 5 = 35*

*8 * 4 = 32*

*9 * 3 = 27*

*10*2= 20*

*11 * 1 = 11*

He made a ladder from 7 to 11 and from 5 to 1.

Is that an interesting observation? For me, it is.

It is interesting to note that there is an interval between generating the answers and proposing a pattern: about 5 minutes. Another factor linked to creativity is the questioning constructed at the end by the student, "is that an interesting observation? For me, it is," since researchers in creativity (Kaufman & Beghetto, 2009) and in creativity in mathematics (Nadjafikhaha & Yaftian, 2013) point out that creativity can be analysed as an intrapersonal element. Regardless of the type of judgment that the student's production receives from a group of reviewers experts in mathematics and creativity, for him, the production made sense and was recognised as something interesting (Kaufman & Beghetto, 2009). This perception of the student shows that creative feedback may have acted in fostering a self-perception of the creative capacity, boosting the awakening of intrinsic motivation for involvement with other mathematical tasks (Gontijo, 2020).

In the rectangles Student B built, he noticed that there was a relationship between the measurements of the sides, identifying that the larger the measurement of the base, the smaller the area delimited. Student C, in turn, perceived a logic linked to the product of the values worked by him: "[u]sing integers, I did not notice any pattern. Using fractions, with 0.5 at the end, all ended in 0.75. And for those ending in 0.25 and 0.75, all ended with 0.0075."

As the video call lasted long, we could not ask the student to develop hypotheses about applying this logic to products involving numbers with such characteristics. From the work with the rectangles, he could have reflected on the results of multiplications between decimal numbers with those characteristics, expanding his fluency and flexibility of thought, and might have also, in comparison with the productions of his classmates, presented original patterns.

Student D brought a logic similar to that reported by student A, although he demonstrated as a major challenge the attempt to explain the logic perceived:

> [Student]: *1x11*
>
> *2X10*
>
> *3x9*
>
> *4x8*
>
> *5x7*
>
> *Now all I have to do is try to explain it.*
>
> [Teacher]: *Cool. If you want, you can send an audio message explaining it* [suggestion to stimulate the student's communicative expression].
>
> [Student]: *I'm trying to think of the best way to explain this.*

After about 11 minutes, the student says:

> [Student]: *If we use the possibilities of area with natural numbers, if we organise in this way, the multiplier will be in increasing order and the multiplicand in decreasing order.*

The last question asked the students was: *can you determine the measurements of the rectangle that generate the smallest area and also the largest area while maintaining the perimeter equal to 24cm? If so, what are they and how to find them?*

The beginning of this stage of the activity was based on the communicative process of conceptual clarification, observing Brookhart's (2008) considerations about the content of the feedback: focus, function, clarity, specificity, and tone. Students had doubts about the properties and characteristics of the quadrilaterals, questioning whether a rectangle could have equal measurements of base and height, that is, whether a rectangle could also be considered a square. Considering that the work with properties and characteristics of the quadrilaterals begins in the initial years of elementary school and that those topics pervade other moments of the students' schooling, the feedback must be encouraging to stimulate the collection of the information that students already have and the establishment of relationships between them to clarify the doubt presented. The feedback cannot suggest that doubt is the result of neglect in studies or incompetence of students in the learning process, but should motivate them to overcome the difficulties encountered.

After clarifying the doubts, the students began to answer the question until they reached a consensus on the measures that generate the rectangle with the largest area, 36cm². Basically, the students claimed to have found this value from the analysis they had done when asked about the presence of some pattern between the rectangles they produced in the previous activities.

As for the smallest area rectangle, students C and D immediately proposed answers with decimal dimensions, but only student C offered a detailed answer:

> *For the smallest* [area] *I reached up to 0.0000000012.*
>
> *11.9999999999×0.0000000001. And the more zeros I put in the dimension, the more the area number extends.*

Student D, although presenting decimal measurements as dimensions for the smallest rectangle, presented only 11.5 and 0.5. Below is an excerpt from the dialogues built between the teacher and student, through constant *feedback* :

> [Teacher]: Have you *tried with any decimal less than 0.5?*
>
> [Student]: *I tried, but following the same pattern as the others, it would not give the perimeter of 24. Maybe there are smaller possibilities, but out of this pattern. I'm checking it now.*

After a few moments, he adds:

> [Student]: *0.9x11.1. Now I'm sure.*

After a few seconds, he adds:

> [Student]: *So, it would be very difficult to find the smallest perimeter.*

And after about a minute, the student writes:

> [Student]: *The possibilities are infinite, since it is possible to have infinite decimal places.*

The constant elaboration of ideas at this time offers clues that confirm the *feedback* potential for stimulating the action of creative thinking.

As for student A, after being asked if he could not have a rectangle with a base greater than 11 that met the perimeter condition equal to 24, he proposes new answers, saying that the smallest area rectangle could be 11 by 0.1. But then, he adds:

> *Or you can go even lower*
>
> [...]
>
> *Asking for the smallest number is way down with the decimals.*

A similar reasoning is developed by student B.

A collective feedback was proposed to complete the activity, to enable the participating students to talk about what they had perceived during the work to find the dimensions that would generate the smallest possible area rectangle.

It is worth mentioning that, through the dialogue built with the constant feedbacks focused on the development of creativity, the students registered different ideas. Although these ideas were valuable only for those who created them, they represented creation and innovation opportunities in the learning process. Thus, an example of the potential that this strategy has in the development of creativity in mathematics.

CONCLUSIONS

Public policies, institutions, researchers and teachers have increasingly defended the need to stimulate individuals' creative thinking. Based on the so many innovations present in our lives, new careers are emerging in society and with them, the need for workers to develop new skills.

It is often said that we need to develop individuals' creativity from the beginning of their school life. To this end, we presented here the concept of creative feedback, which can be treated as a strategy the teacher can adopt in the classroom to foster students' creativity skill.

There are different possibilities of developments in this research, such as the possibility of investigating the development of critical thinking, creative peer feedback, and the potential of using creative feedback to stimulate creativity in different areas of knowledge.

As for the first point, critical thinking in mathematics would develop as a consequence of the constant exchange of perceptions between the individuals involved; after all, in each feedback, the subject is led to reflect, analyse, and judge their own ideas. Regarding creative feedback, although this article focused on feedback between teacher and student, it is possible to analyse the developments of creative *feedback* between peers, from one student to the other. In this case, creativity and critical thinking develop even more intensely, especially with those who provide the *feedback*, since they must also analyse their peers' answers.

Finally, even if this article addresses feedback aiming to foster creativity in mathematics, it is valid to suggest the experimentation of this strategy for the development of creativity in different areas of knowledge, since generating ideas is present in the human act.

AUTHORSHIP CONTRIBUTION STATEMENT

Authors W. W. V. B., C. H. G. and M. G. F. contributed equally to the research and writing of this article.

DATA AVAILABILITY STATEMENT

The data supporting the results of this study will be made available by the corresponding author, W. W. V. B., upon reasonable request.

REFERENCES

Alencar, E. M. L. S. & Fleith, D. S. (2003). Contribuições teóricas recentes ao estudo da criatividade. *Psicologia: Teoria e Pesquisa*, *19*(1), 1-8.

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology*, *45*(2), 357-376.

Amabile, T. M. (1989). *Growing up creative*. The Creative Education Foundation Press

Amabile, T. M. (1996). *Creativity in context: Update to the social psychology of creativity*. Westview Press.

Kaufman, J. C. & Beghetto, R. A. (2009). Beyond big and little: the four C model of creativity. *Review of general psychology*, *13*(1), 1–12.

Brookhart, S. (2008). *How to give effective feedback to your students*. Association for Supervision and Curriculum Development (ASCD).

Bughin, J., Hazan, E., Lund, S., Dahlström, P., Wiesinger, A. & Subramaniam, A. (2018). *Skill shift: Automation and the future of the workforce*. McKinzey Global Institute.

Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In Sternberg, Robert J. (ed.) *Handbook of Creativity*. (p. 313-335). Cambridge University Press.

Garnica, A. V. M. (2004). História Oral e educação Matemática. In: Borba, M. C.; Araújo, J. L. (Orgs.) *Pesquisa Qualitativa em Educação Matemática*. Autêntica.

Gil, A. C. (2008). *Métodos e Técnicas de Pesquisa Social*. 6ª ed. Atlas.

Gonçalves, F. do C., Fleith, D. S. & Libório, A. C. O. (2011). Criatividade em aula: percepção de alunos de dois estados brasileiros. *Arquivos Brasileiros de Psicologia***.** Rio de Janeiro, *63*(1), 22-30.

Gontijo, C. H. (2007). *Relações entre criatividade, criatividade em matemática e motivação em matemática de alunos do ensino médio*. 194f. Tese (Doutorado em Psicologia) - Instituto de Psicologia, Universidade de Brasília, Brasília.

Gontijo, C. H. (2015). Técnicas de criatividade para estimular o pensamento matemático. *Educação e Matemática*, 135, 16-20.

Gontijo, C. H. (2020). Relações entre criatividade e motivação em matemática: a pesquisa e as implicações para a prática pedagógica. In Gontijo, C. H. & Fonseca, M. G. (Org.). *Criatividade em Matemática: lições da pesquisa*. (p. 153-172). CRV.

Gontijo, C. H., Carvalho, A. T., Fonseca, M. G. & Farias, M. P. (2019). *Criatividade em matemática: conceitos, metodologias e avaliação*. 1ª. ed. Editora da UnB.

Grégoire, J. (2016). Understanding creativity in mathematics for improving mathematical education. *Journal of Cognitive Education and Psychology*, *15*(1), 24-36.

Guilford, J. P. (1950) Creativity. *American Psychologist*, 5, 444-454.

Kanhai, A. & Singh, B. (2017). Some environmental and attitudinal characteristics as predictors of mathematical creativity. *International Journal of Mathematical Education in Science and Technology*, *48*(3), 327-337.

Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. & Dewhurst, M. (2017). *A future that works: automation, employment, and productivity*. McKinsey Global Institute.

Minayo, M. C. (2002). *Pesquisa Social: teoria, método e criatividade*. Vozes.

Nadjafikhaha, M. & Yaftian, N. (2013). The frontage of Creativity and Mathematical Creativity. *Procedia – Social and Behavioral Sciences*, 90, 344-350.

Petrovici, C. & Havârneanu, G. (2015). An educational program of mathematical creativity. *Acta Didactica Napocensia. Romania*, *8*(1), 13-20.

Plucker, J. A., Beghetto, R. A. & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*(2), 83–96.

Rogers, C.R. (1959). Towards a theory of creativity. In Anderson H.H. (ed.), *Creativity and its cultivation*. Harper and Row.

Sternberg, R. J. & Lubart, T. (1991). An investment theory of creativity and its development. *Human Development*, 34(1), 1-31.

Sternberg, R. J. & Lubart, T. (1993). Creative giftedness: a multivariate investment approach. *Gifted Child Quarterly*, *37*(3), 7-15.

Sternberg, R. J. & Lubart, T. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. Free Press.

Sternberg, R. J. & Lubart, T. (1996). Investing in creativity. *American Psychologist*, *51*, 677-688.

Vergnaud, G. (1993). Teoria dos campos conceituais. In Nasser, L. (Ed.) *Anais do 1º Seminário Internacional de Educação Matemática*. (p. 1-26). SBEM: Rio de Janeiro.

Vincent-Lancrin, S., González-Sancho, C., Bouckaert, M., De Luca, F., Fernández-Barrera, M., Jacotin, G., Urgel, J. & Vidal, Q. (2020) *Desenvolvimento da criatividade e do pensamento crítico dos estudantes: o que significa na escola* / [coordenação geral Instituto Ayrton Senna; tradução Carbajal Traduções]. Fundação Santillana.

Yin, R. K. (2010). *Estudo de caso: planejamento e métodos*. 4. Bookman.

Wallas, G. (1926). *Art of thought*. Jonathan Cape.

World Economic Forum (2018). *The future jobs report*. Centre for the New Economy and Society.

Zhou, J. (2008). Promoting creativity through feedback, In Zhou, J. & Shalley, C. E. (Eds.). *Handbook of Organizational Creativity* (p. 125-145). Taylor & Francis.