Zetetiké

DOI: 10.20396/zet.v31i00.8672198

(Re)Design of Mathematical Tasks in the Light of Didactic Suitability and Creativity Criteria

(Re)Desenho de Tarefas Matemáticas à luz dos Critérios de Idoneidade Didática e Criatividade

Adriana Santos Sousa[1]

Tânia Cristina Rocha Silva Gusmão[2]

Abstract

This study presents the analysis of creative competence in (future) teachers to design mathematical tasks or redesign existing tasks involving Quadratic Functions and what knowledge and criteria they use to (re)design them, based on online training using synchronous communication (Google Meet) and asynchronous (Virtual Learning Environment). The investigation of a qualitative and interventional nature provided the participants with theoretical and practical situations for exchanging ideas and experiences for the (re)design of tasks. The analysis is based on the Cycle of Studies and Design of Tasks in the light of the Didactic Suitability Criteria. The results indicate that the participants rarely use open tasks, find it challenging to be creative and design authorial tasks, and that they tend to start the creativity process by redesigning tasks.

Keywords: Design of Mathematical Tasks, Creativity, Teacher Training.

Resumo

Este estudo apresenta a análise da competência criativa em (futuros) professores para desenhar tarefas matemáticas ou redesenhar tarefas já existentes envolvendo Funções Quadráticas e quais conhecimentos e critérios utilizam para (re)desenhá-las, a partir de uma formação online utilizando a comunicação síncrona (*Google Meet*) e assíncrona (Ambiente Virtual de Aprendizagem). A investigação de natureza qualitativa e interventiva proporcionou aos participantes situações teóricas e práticas para troca de ideias e experiências para o (re)desenho de tarefas. A análise está fundamentada no Ciclo de Estudos e Desenho de Tarefas à luz dos Critérios de Idoneidade Didática. Os resultados apontam que os participantes pouco utilizam tarefas abertas; encontram dificuldades para serem criativos e desenhar tarefas autorais e que a tendência é iniciar o processo de criatividade realizando redesenho de tarefas.

Palavras-chave: Desenho de Tarefas Matemáticas, Criatividade, Formação de Professores.

Introduction

The transformations in our society, especially in the education sector, have demanded

Submetido em: 20/12/2022 – **Aceito em**: 01/08/2023 – **Publicado em**: 19/12/2023

[1] Ph.D. student and Master in Science Education and Teacher Training at the State University of Southwest Bahia (UESB), Jequié-BA campus, Brazil. Email: cjccadriana@gmail.com. ORCID: https://orcid.org/0000-0002-2472-8587

[2] Ph.D. in Mathematics Didactics from the University of Santiago de Compostela (USC), Galicia, Spain (2006). Full Professor at the State University of Southwest Bahia (UESB), Vitória da Conquista-BA, Brazil. CNPq-PQ-2 Research Productivity Fellow. Email: professorataniagusmao@gmail.com. ORCID: https://orcid.org/0000-0001-6253-0435

DOI: 10.20396/zet.v31i00.8672198

more proactive behavior from educators in proposing pedagogical strategies and tasks capable of provoking students' critical and creative thinking development.

This scenario implies the development of actions that encourage investigation, reflection, critical analysis, imagination, and creativity in constructing knowledge (Brasil, 2018), as indicated by the Common National Curriculum Base (BNCC) in one of the general competencies of Basic Education.

To achieve the competencies set out in the BNCC, educators often face difficulties when it comes to choosing methodologies and creating materials that develop, for example, creative mathematical thinking in the classroom. Putting creative teaching into practice involves going into teacher training and preparing them to (re)design creative mathematical tasks according to the mathematical object studied. The concept of tasks refers to Gusmão (2019, p.1) as being "a broad set of proposals, encompassing problems, activities, exercises, projects, games, experiments, investigations, etc. that the teacher takes into the classroom with a view to their students' mathematical learning."

This study reflects on the Cycle of Study and Design of Tasks (CSDT) involving Quadratic Functions, especially creativity. The analysis is based on the Criteria of Didactic Suitability (CDS) of the Ontosemiotic Approach to Mathematical Knowledge and Instruction (EOS). The "Training Cycle in Task Design: Quadratic Function and Creativity" was one of the extension actions of the Group of Studies and Research in Didactics of Experimental Sciences and Mathematics (GDICEM) of the State University of Southwest Bahia (UESB), of which the authors are members.

The course was part of a pilot study for the research project "The development of creative competence in (future) teachers for the design of mathematical tasks," the general aim of which is to analyze the process of developing creative competence in (future) teachers for designing mathematical tasks or redesigning existing tasks and what knowledge and criteria they use to (re)design them.

Continuing Education for Mathematics Teachers

The National Education Council (CNE)/CP resolution of December 20, 2019, defines the National Curriculum Guidelines and establishes the Common National Base for the Initial Training of Basic Education Teachers (BNC-Formação). This document states, among the general teaching competencies, that licensed teachers should value ongoing training for professional practice, update themselves in their field, and appropriate new knowledge and experiences that enable them to improve professionally (Brazil, 2019).

From this perspective, the professional development of teachers is understood as a continuous process of learning and growth in which teachers improve their practice and develop skills and knowledge to implement an increasingly high-quality education for their students, trying to overcome problems such as disinterested students, low learning rates, indiscipline in the classroom, the need for innovation, etc.

DOI: 10.20396/zet.v31i00.8672198

Continuing education courses are an alternative for overcoming pedagogical and methodological gaps in undergraduate courses. This is important because it is a way for teachers to keep up to date with current trends and develop skills in their area of teaching, as well as help them to adapt to the needs of their students and the demands of the modern world.

During training, according to Freire (2008, p. 21), there is an alternation of formative action centered sometimes on the trainer and sometimes on the trainee, relating that "there is no teaching without discourse [...] Those who teach learn by teaching and those who learn to teach by learning". The teacher assumes the posture of a continuous learner. They take on the role of transforming, critical and creative agents, articulating the needs and desires of the students with their actions in the classroom. This movement builds knowledge by sharing ideas, materials, methodologies, and actions to improve teaching-learning.

Continuing teacher education courses have been the focus of several academic studies by Font and Breda (2015); Godino (2009); Godino and Batanero (2009); Gusmão (2019, 2020); Borba, Malheiros and Amaral (2011), Fiorentini (2003); Fiorentini and Lorenzato (2012), among others. The results of these investigations indicate that taking part in training cycles allows for individual and/or collective deepening of knowledge of the curriculum and reflection-action-transformation of practice.

The restlessness of teachers, especially math teachers, in their quest to update concepts and methodologies to improve their classroom practice is present in the participation in courses developed by the GDICEM group. In this article, we will share the research carried out in the "Training Cycle in Task Design: Quadratic Function and Creativity" on the development of teachers' creative competence in (re)designing tasks following the precepts of the Cycle of Studies and Task Designs, which we will describe below.

The Cycle of Studies and Task Designs (CSDT)

The Cycle of Studies and Task Designs (CSDT) is a research method based on the theoretical and methodological aspects of the Criteria of Didactic Suitability (CDS) discussed by Godino, Batanero and Font (2008). The CSDT has been built and developed collectively and collaboratively by the participants of the GDICEM group and proposes "a research method aimed at the study and design of own, original or modified tasks to achieve improvements in the processes of teaching and learning mathematics" (Gusmão & Font, 2020, p.668). CSDT is designed in stepss, as described in Figure 1:

DOI: 10.20396/zet.v31i00.8672198

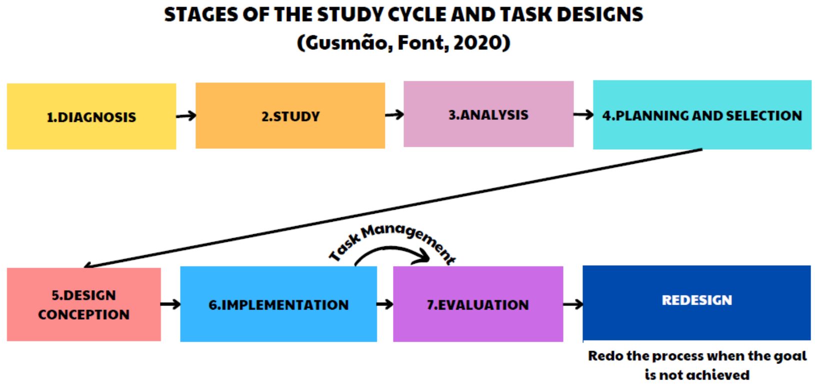

Figure 1: Phases of the CSDT
Source: First author's organization

1. Diagnosis - definition of the mathematical object to be studied and the problems surrounding it, based on dialog with teachers.
2. Study - the study of the mathematical content and/or problem in greater depth, including theory, methodology, and various resources; study of the Didactic Suitability Criteria (epistemic, cognitive, emotional, interactional, mediational, and ecological) and the aspects observed in the (re)design of tasks (nature of the task; cognitive demand; how much the activity allows for interaction, fun, inclusion; whether it provides for the development of simple to complex thinking; identification of the type of task: exercises, games, problems, etc. and whether it allows for original solutions and application in other contexts);
3. Analysis - appraisal and critique of plans, teaching sequences, various tasks produced by the participants and available in academic research, making suggestions for improvement based on criteria previously agreed by the teachers and later by the criteria of task design and didactic suitability;
4. Planning and selection - planning, selecting, and improving the tasks with criteria, observing variables such as time, space, and material resources available for preparing and making the tasks;
5. Design/conception - creating and/or adapting tasks taking into account the design and teaching suitability criteria, the educational objectives, and intentions;
6. Implementation - implementing the designed tasks in the classroom to test them;
7. Evaluation - the evaluation is continuous, and the implementation notes are used to guide the redesigns or new designs;
8. Task redesign - corrections and adjustments to inconsistencies to improve the designs and more effective learning. (Gusmão & Font, 2020).

Supported by the CSDT, this training provided a deeper understanding of mathematical concepts related to the Quadratic Function, as well as expanding the repertoire of teaching methodologies using hands-on tasks and/or technologies and pedagogical

DOI: 10.20396/zet.v31i00.8672198

resources (apps, games, stories, among others), as detailed in the methodological section of this article.

The Criteria of Didactic Suitability (CDS)

The Ontosemiotic Approach to Mathematical Knowledge and Instruction (EOS) is an "ontological and semiotic model of cognition, which provides criteria for identifying the possible states of epistemic and cognitive trajectories and the use of 'negotiation of meanings' as a key notion for the management of didactic trajectories" (Godino, Batanero & Font, 2008, p.11), whose origins lie in the research carried out by Professor Godino (2008) in collaboration with Batanero (2008, 2009) and Font (2008, 2015); Gusmão (2006); Hummes, Font and Breda (2019); Kaiber, Lemos and Pino-Fan (2017) among other authors. The EOS provides theoretical and methodological guidance for research with a set of tools articulated in five sub-competencies (analysis of global meanings; management of didactic configuration; normative analysis, Ontosemiotic analysis, and didactic suitability analysis).

The sub-competency identified as the Criteria of Didactic Suitability (CDS) is highlighted, which presents the six dimensions related to the mathematical teaching and learning process. Since suitability is understood as adequate or suitable processes, the dimensions of the CDS serve as a guide for planning, designing, implementing, analyzing, and evaluating teaching and learning processes, as shown in Figure 2.

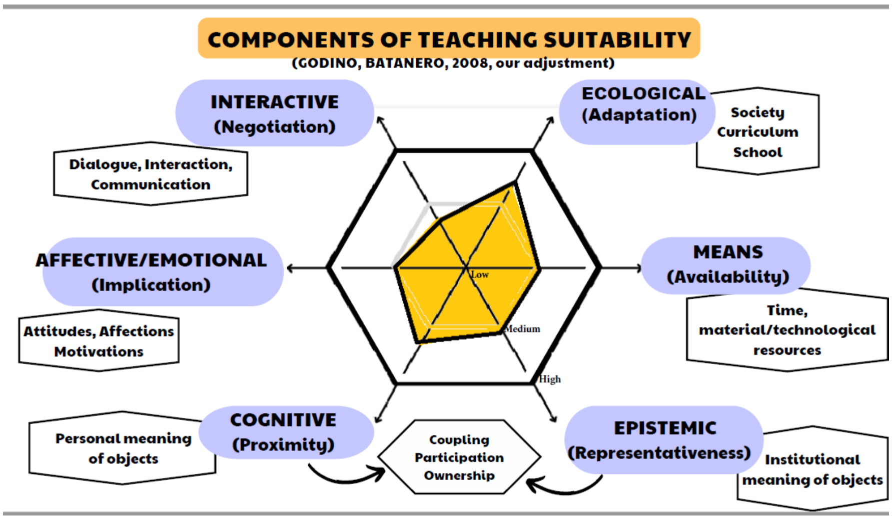

Figure 2: Components of the CDS
Source: Godino, Batanero (2008, adapted)

a) Epistemic suitability: to assess whether the mathematics being taught is "good mathematics," related to teaching mathematics without ambiguities or errors;
b) Cognitive suitability: to assess, before starting the instructional process, whether what is intended to be taught is within a reasonable distance of what the students know and, after the process, whether the learning acquired is close to what was designed to be taught; whether there is an expansion of the student's knowledge;
c) Interactional suitability: to assess whether the interactions resolve students' doubts and difficulties;

DOI: 10.20396/zet.v31i00.8672198

d) Mediational suitability/*means*: to assess the suitability of the material and time resources used in the instructional process;
e) Emotional/affective suitability: to assess the involvement (interest and motivations) of students during the instructional process;
f) Ecological suitability: to assess the suitability of the instructional process to the center's pedagogical project, curriculum guidelines, and social and professional environment conditions. (Hummes, Font & Breda, 2019, p.67).

In our research, the CDSs have provided theoretical support for the CSDT and helped us to understand the development of math teachers' creative competence. In this study, competence is understood as "the mobilization of knowledge (concepts and procedures), skills (practical, cognitive and socio-emotional), attitudes and values to solve complex demands of everyday life, the full exercise of citizenship and the world of work," a definition presented in the Common National Curriculum Base (BNCC) (Ministério da Educação, 2018, p.8).

CDSs and the development of Creative Competence in Mathematics

Teachers often face difficulties when designing interesting tasks (Gusmão, 2019) that develop students' creativity and autonomy, demystifying the idea of mathematics as something difficult, complicated, and restricted to a few. One of the general teaching competencies states that teachers, after their initial training, should be able to "research, investigate, reflect, carry out critical analysis, *use creativity* and seek technological solutions to select, organize and plan challenging, coherent and meaningful teaching practices" (Ministério da Educação, 2019, p.13, emphasis added).

Although creativity is inherent to human beings and an increasingly necessary skill in our society, some teachers still don't feel confident working with creativity and for creativity (Beghetto, 2013). In their book "Can creativity be taught?", Torrance and Torrance (1974) reveal, through 142 experiments carried out with students using different teaching methods, that creativity can be taught by offering motivating and facilitating conditions, highlighting those that involve cognitive and emotional functions between teachers and students. They also point out that creative thinking is

> a natural process in human beings, through which a person becomes aware of a problem, a difficulty, or even an information gap, for which they have not yet learned the solution; they then look for possible solutions in their previous experiences or the experiences of others. They formulate hypotheses about all possible solutions, evaluate and test, modify, re-examine, and communicate the results (Torrance & Torrance,1974, p.2).

Therefore, for teachers and students to identify possible solutions to a problem and for creative competence to be observed, it is necessary for tasks to provide students with the opportunity to develop creative thinking, which is characterized by fluency (the emergence of a large number of ideas on the same topic); flexibility (adapting thinking to different categories of responses); originality (unusual, infrequent responses); elaboration (detailing an idea) and evaluation (choosing one or more ideas presented) (Alencar, 1995). Therefore,

DOI: 10.20396/zet.v31i00.8672198

teachers' attention to the criteria for analyzing, selecting, and producing tasks should be reinforced to provide students with creative learning experiences.

Regarding mathematical creative competence, Kattou, Christou and Pitta-Pantazi (2016) point out that for a person to be mathematically creative, they must have content knowledge, general creative skills, and fluid intelligence. Creativity in mathematics is defined by Gontijo (2007, p. 37) as "the ability to come up with numerous appropriate solutions to a problem situation." In this way, the connection between creativity and mathematics is close and essential, as it involves thinking (and acting) originally and innovatively to find solutions, combining ideas and concepts to find solutions to problems.

The study of mathematical creativity, the creative mathematical competence of teachers and students, and the design and insertion of stimulating tasks in classroom practice to develop students' critical and creative mathematical thinking have been the subject of research carried out by Gontijo (2007); Gontijo, Silva and Carvalho (2012); Gontijo, Carvalho and Fonseca (2019); Gontijo and Fonseca (2020); Sousa (2018); Rodrigues (2019); Pereira (2019); Moreira and Gusmão (2020) among others. These studies point to the importance of stimulating and developing creativity in the classroom with attitudes, techniques, tasks, strategies, teaching resources, and an environment that fosters the creative potential of students and teachers. This article will discuss the criteria used to (re)design creative tasks.

Gusmão (2019) observes that the mathematical creative process is neither easy nor quick and that teachers are usually able to redesign tasks by making modifications to them. Still, the design process involving originality is more challenging to achieve. Therefore, to help design authorial, own, original, and creative tasks, teachers and future teachers can consider the CSDT indicators (Figure 3) crossed by creativity, as described below.

DOI: 10.20396/zet.v31i00.8672198

TASK DESIGN INDICATORS / EPISTEMIC SUITABILITY
TDI-E1. Is the wording clear, correct, and appropriate for the level of teaching?
TDI-E2. Do they use different languages and forms of mathematical expression (verbal, graphic, symbolic, pictorial, etc.)?
TDI-E3. Is the selection of tasks representative and varied, and does it include closed and open-ended tasks?
TDI-E4. Are the tasks of different types?
TDI-E5. Do they promote hypothesizing and open thinking (reversible, flexible, off-center thinking) and encourage the use of argumentation and justification processes?
TASK DESIGN INDICATORS / COGNITIVE ABILITY
TDI-C1. Does it build on students' prior knowledge?
TDI-C2. Do they expand, reinforce and systematize knowledge?
TDI-C3. Do they respect the students' level of cognitive development?
TDI-C4. Do they encourage the use of different, creative, and original resolution strategies?
TDI-C5. Do they meet different learning objectives and lead the solver to develop different cognitive and metacognitive skills?
TASK DESIGN INDICATORS / INTERACTIONAL SUITABILITY
TDI-I1. Do you foresee moments of dialog and argumentation between students or between teachers and students?
TDI-I2. Do you encourage individual, pair, or group resolution?
TDI-I3. Do they allow for cognitive conflict (in the Piagetian sense) and the negotiation of meanings?
TDI-I4. Do they encourage responsibility for the study (exploration, formulation, and validation)?
TASK DESIGN INDICATORS / MEDIATIONAL SUITABILITY
TDI -M1. Do they provide or indicate using manipulable and/or technological materials to help with performance?
TDI -M2. Do they provide enough time to complete the task and maintain concentration and interest?
TDI -M3. Are the times appropriate to the types of tasks (reproduction, connection, reflection, etc.)?
TDI -M4. Do they provide adequate space for them to be carried out?
TDI -M5. Do they provide for moments of practical experimentation to help understand concepts and their applicability?
TASK DESIGN INDICATORS/EMOTIONAL SUITABILITY
TDI-Em1. Do they promote interactivity, attraction, fun, and inclusion, raising self-esteem, the feeling of inclusion, the opening up of subjectivity, and a taste for mathematics?
TDI-Em2. Do they value different types of reasoning and responses?
TDI-Em3. Do they encourage participation and interest?
TDI-I4. Do they promote the perception of the usefulness of mathematics in life and work?
TDI-I5. Do they promote student involvement in solving tasks (devolution of learning in Brousseau's sense)?
TDI-Em6. Do they present achievable challenges, triggering increasingly complex levels of thinking?
TDI-Em7. Do they present the application and beauty of mathematics?
TASK DESIGN INDICATORS/ECOLOGICAL SUITABILITY
TDI-Ec1. Do they take into account official curriculum documents (national and local)?
TDI-Ec2. Do they seek to link different mathematical contents and areas of knowledge?
TDI-Ec3. Are the tasks contextualized with the social and cultural environment?
TDI-Ec4. Are the contents of the tasks useful for social and working life?

Figure 3: Indicators of Task Design in Light of the Criteria of Didactic Suitability
Source: (Gusmão & Font, 2020, pp. 686-687, numerical identification elaborated by us)

These indicators can guide teachers in analyzing, selecting, and creating their own tasks and redesigning tasks with a focus on creativity.

Methodological path

The training cycle served as a pilot study for the research "The development of creative competence in (future) teachers for the design of mathematical tasks" at the doctoral level. The training was established as the basis for action research to study, understand and explain its effects (Chizotti, 2011).

The training was supported by GDICEM members and supervised by the group's coordinator. The total workload was 120 hours, divided into two parts, both focusing on creativity:

a) the general part, with 40 hours, covered the concepts of the Cycle of Studies and Task Design (CSDT) and the Criteria of Didactic Suitability. At this stage, articles and tasks involving the topic were analyzed;

b) the specific part, developed in 80 hours, with the study of the mathematical object

DOI: 10.20396/zet.v31i00.8672198

(Quadratic Function) and (re)design of tasks. Various ways of presenting the content were presented for study and analysis based on the CSDT criteria; reading and discussing articles; practical activities with Excel and concrete material; games and applications etc. This part was developed by three doctoral students, including the first author, also members of the GDICEM group.

The course ran from August to November 2022, with weekly synchronous meetings on the Google Meet platform. The study materials were available in the Virtual Learning Environment (VLE), and asynchronous interactions took place on the discussion forums. The WhatsApp messaging group was used to exchange messages and warnings about the course quickly.

Because it was online, the course was attended by thirty-seven students, seven of whom were undergraduates, and thirty teachers from various regions of Brazil (North, Northeast, Southeast, and South) who worked in different grades and levels of education, a factor that enriched the discussions during the meetings. Of the 37 participants, 16 completed only the first phase, 16 completed the entire course, and five dropped out along the way. The main reason for these dropouts was lack of time.

The research, of an interventional qualitative nature, did not focus solely on the results, but aimed to understand the process, taking into account the behaviors, interventions, interactions, and productions from the perspective of the participants (Bogdan & Biklen, 1994). Authors such as Borba and Araújo (2018); Flick (2009); Yin (2016); Creswell and Creswell (2021) have similar positions when they indicate the importance of analyzing the process and not just the results or products obtained in a training course.

The interventional nature of the training allowed participants to collaboratively "test ideas and curricular proposals, teaching strategies and resources, develop training processes in which the researchers and other subjects involved act with the intention of solving practical issues while producing systematized knowledge" (Teixeira, Neto, 2017, p. 1056). Thus, synchronous meetings and asynchronous discussions became environments conducive to learning through dialog, exchange of ideas, analysis of tasks, and identification and solution of problems with the collaboration and participation of all. These social and interpersonal interactions between participants and researchers, according to Chizotti (2011), are allowed and are part of the investigative process.

Interviews, questionnaires, field diaries, video recordings (online meetings), and tasks were the instruments used to produce data to verify and analyze the effects of the training cycle on the development of teachers' mathematical creativity in the (re)design of tasks. And as already mentioned, the analysis followed the precepts of the Cycle of Study and Design of Tasks (CSDT) and the Criteria of Didactic Suitability (CDS), focusing on creativity.

Analysis of the Training Cycle

The analysis of this study focused on the development of creative competence in the

DOI: 10.20396/zet.v31i00.8672198

(re)design of tasks, taking into account the CSDT in the light of the CDSs.

Regarding the Diagnostic step, teachers could select the mathematical object to study when registering. The majority chose Quadratic Functions. The preference for this content was justified by the students' difficulties in constructing the concept of function, identifying variables, graphical and algebraic operations, practical application of the concepts in an interdisciplinary way and real situations, and constructing graphs, among others. The difficulties in working with this content are also revealed in academic research carried out by Maia (2007), Kieran (1992), Gonçalves (2019), Silva (2019), Ferreira and Pires (2020), Ninow and Kaiber (2016), Bernadino, Gama and Rezende (2017). In addition, it should be noted that the Program for International Student Assessment (PISA) (Ministério da Educação, 2018, p.114) indicates that students lack skills in reading, interpreting, and making connections between information and in "mastering symbolic and formal mathematical operations and relationships to develop new approaches and strategies that allow them to deal with new situations."

The following steps involved studying and deepening concepts related to Quadratic Functions, task design, didactic suitability criteria, and creativity. The interactions and exchanges of ideas that took place in the synchronous meetings indicated that they had previously read the articles posted on the VLE.

Based on the studies carried out, we began the task analysis step, and among the tasks presented was: *Determine the vertex of the parabola* $y= 3x^2 - 12x + 11$. The teachers considered it an uncreative, simple, closed exercise with little cognitive demand since applying a formula would solve the problem. Given this diagnosis, the teachers were challenged to redesign the task to make it more creative, exciting, and provocative.

In response to this challenge, teachers GB (Figure 4), AS (Figure 5), and AP (Figure 6) gave the following answers, respectively, in the discussion forum in the virtual learning environment:

> A data estimate indicates that the number of ticket sales for the Bahia Winter Festival (FIB/2022) can be described by the function F (t) = 3t2 - 12t +11, where F (t) is the balance, in Reais, on day t, for t ϵ [1, 30]. Given these estimates for ticket sales, we will find out the following:
>
> a) The balance value in Reais for FIB/2022 on day t =26.
>
> b) The maximum and minimum sales over a 30-day period?

Figure 4: Task modified by Teacher GB posted on the Discussion Forum)
Source: (VLE, 2022)

DOI: 10.20396/zet.v31i00.8672198

Freestyle is a motocross sport where you must jump on a motorcycle from one ramp and land on another, performing maneuvers. A motorcyclist's jump described a trajectory represented by the function $y=3x^2-12x+ 11$. Calculate the maximum height reached in the jump.

Figure 5: Task modified by Teacher AS posted on the Discussion Forum)
Source: (VLE, 2022)

A household utensil factory will produce shells and use the expression $3x^2 - 12x +11$ to find the depth and create the design for this item. Help the project manager to identify this value.

Figure 6: Task modified by Teacher AS posted on the Discussion Forum)
Source: (VLE, 2022)

We observed a significant change in the re-presentation of the initial problem. There is a deconstruction and reframing of the problem since the statements are contextualized, more provocative, and related to everyday life. Thus, we can identify some of the Ecological Task Design Indicators (TDI-Ec) used by the teachers: the three tasks meet the TDI-Ec1 indicator, as the content is included in official national and local curriculum documents; they are contextualized according to local and cultural events and real-life situations (TDI-Ec3), and they link mathematical concepts to other areas of knowledge (TDI-Ec2).

We can see the Epistemic indicator, especially TDI-E1, in tasks A and C, due to the straightforward, correct, and appropriate language for the level of teaching. However, task B is inconsistent in the concept, even with explicit language, as the teacher asks for the maximum point. At the same time, the coordinates of the vertex of the parabola indicate the minimum point *"function $y=3x^2-12x+ 11$. Calculate the maximum height reached in the jump"*. Task A also asks for the maximum value, but the teacher determines the interval for this calculation to be carried out.

Compared to the original task, which required little cognitive effort from the student, in the redesigns, we can see the Cognitive Indicator; since the teachers took into account the students' previous knowledge (TDI-C1), the expansion, reinforcement, and systematization of knowledge (TDI-C2) and respect for the student's level of cognitive development (TDI-C3) when redesigning the task.

Even though they used contexts capable of engaging their students, the teachers did not redesign the task in such a way as to explore characteristics of creative mathematical thinking, such as the possibility of multiple and unusual answers.

In a synchronous moment, the task "Which element does not belong to the group?" (Figure 7) asked participants to indicate which graph did not belong to the group, justifying their choice.

DOI: 10.20396/zet.v31i00.8672198

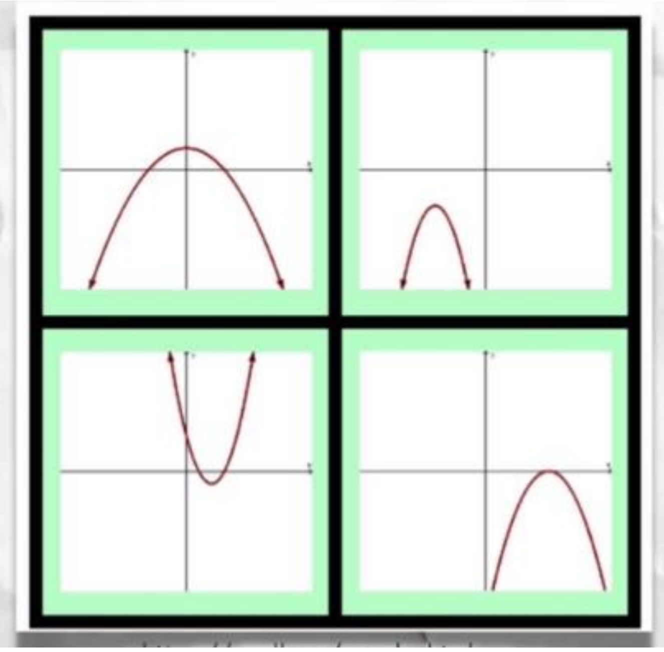

Figure 7: Task "Which element does not belong to the group?"
Source: https://wodb.ca/graphs.html

As soon as the question was asked, the OS teacher immediately replied, *"Top right, because the graph doesn't show a real root. The parameter I used to compare them was the root."* Teacher RP intervened by replying, *"The first one. Why? Because it's the only one that touches the axis. [...]"* After some reflection, she corrected, *"because it's symmetrical."*

In the face of teacher RP's participation, teacher OS, who had already chosen the first graph, added: *"I thought about it, and it gave me another view... the first one on the top left is the only one with Y symmetry"*. Teacher GB indicated the fourth graph because it was the only one with a discriminant value equal to zero. Teacher AS indicated the second graph because it was the only one in the third quadrant. Teacher OS added other arguments: *"You could also analyze it according to the situation, the only one with a minimum point, right? It's the third one because the others have a maximum point. That's it."*

The numerous correct answers indicate that the greater our knowledge, the greater the number of patterns, combinations, and connections we can establish (Alencar, 1995). In this way, the fluency of ideas highlights the epistemic indicators, especially TDI-E5, as it promotes hypothesizing, open thinking, and the use of argumentation and justification.

In this task, we also noticed cognitive adequacy in the different and original resolutions (TDI-C4), leading teachers to expand, reinforce and systematize their knowledge (TDI-C2), as stated by teacher RP (2022, synchronous meeting), who concluded that the task doesn't have a single answer and *"no answer here is right or wrong, right? Cool"* and teacher AP (2022, synchronous meeting) when she says that her colleagues' arguments broaden each other's knowledge.

> *One broadens the other's knowledge, right? [...] I realize that one will make the other realize something that perhaps they hadn't seen initially. So it expands, right? For*

DOI: 10.20396/zet.v31i00.8672198

> *example, without numbers, which is strange for them [students] without numbers appearing. It's really nice.*

These exchanges between peers also encourage dialog and argumentation (TDI-I1); they allow conflicts to be generated and meanings to be negotiated (TDI-I3), and they encourage the exploration, formulation, and validation of ideas (TDI-I4). Interactions are considered necessary in the development of creative thinking, as evidenced in the studies by Csikszentmihalyi and Wolfe (2014), who present creativity in a systemic way involving the person (genetics and personal experiences), the domain (cultural and scientific production); the field (social system). They also add that people are more creative in healthy social and cultural environments. A similar position is defended by Beghetto (2013) when he mentions creativity as the result of interaction between the individual and the environment.

Another point highlighted by the participants was the importance of time to solve open-ended tasks so that students can reflect, respond and learn, according to the mediational indicator (TDI-M2). On this subject, teacher RP (2022, synchronous meeting) reported the need to pay attention to this in planning because

> *we propose something, there's a rush for an answer, so that's natural, right? So, [...] give it some time, wait once. Today, I play the question [...] I let them explore until I stop; come on, guys, I've heard the correct answer and allow them to question, but it's tough.*

Regarding the type of task, the teachers felt inspired to create authorial tasks. We would like to highlight teacher AP (2022, synchronous meeting) who, until then, had never had an experience like this, either as a course participant or as a teacher:

> *I liked the task. I believe that this way of approaching questions is a simple thing that we can do with them [students], but I had never asked them in this way, where one could help the other's knowledge [...] There will be more learning between them because they will realize these differences. And there's also the question of participation, right? Perhaps you have doubts. Ah! I understood why my colleague is saying where he got that information from, what he knows about it [...] So I realize that maybe this way of showing the content is better than us coming with a ready-made product, right?*

The excerpts from the teacher's speech point to emotional indicators, i.e., satisfaction with the interactive and fun experience that raised self-esteem, a sense of belonging and recognition (TDI-Em1), valuing the possible paths to answers (TDI-Em2) as well as promoting the triggering of more complex levels of thought (TDI-Em6) and the awakening to include tasks of this type in their planning, even though they still find it challenging to do so.

As the training went on, new provocations were made so that the teachers could (re)design tasks with a creative bias, including the task in a ninth-grade textbook in which the student is asked to take the lead in creating their own task based on the data presented.

DOI: 10.20396/zet.v31i00.8672198

Develop a problem involving the concept of a quadratic function's maximum or minimum point. The value found for y must be a number between 20 and 50 (Marques, Andere, Silva & Caldenucci, 2021, p.24). This challenge was presented synchronously so that participants could create their own tasks and upload their productions to the VLE. In this way, everyone could discuss the different tasks given, the criteria used to create them, and the importance of authorship in developing creativity. Based on this situation, I would like to highlight teacher OS's production (Figure 8) posted on the VLE:

> An experiment was carried out with a pet bottle rocket, propelled by bicarbonate and vinegar, which was launched from the ground on completely flat terrain and without the influence of wind. It was found that:
>
> -The trajectory of the rocket represented a real function of the 2nd degree.
> - At a horizontal distance of 25 m from the launch point, the rocket reached a height of 30 m. - The rocket touched the ground 100 m from the launch point.
>
> a) Was 30 m the maximum height reached by the rocket? Why?
> b) If you answered 'a' in the negative. What was the maximum height reached?
> c) At what horizontal distance from the launch point was the rocket when it reached its maximum height?
> Extra: What is the distance between the launch point and the rocket's maximum height?

Figure 8: Task posted by Teacher OS on the Discussion Forum
Source: (VLE, 2022)

In the process of designing this task, teacher OS (2022, synchronous meeting) reported:

> *in this case, the kick-off was the parameter you gave, right? You calculate the height it has to reach. So, I chose the distance I wanted to launch the rocket, right? I chose that it would be launched at a hundred meters. [...] because I could put it in a more forced situation, right? For example, I shot an arrow upwards from a mark. It fell a meter from my foot. It could have hit my head, right? However, I went for an idea that was closer to reality. So I determined the points that I wanted to be part of the function, right? Which, in this case, was the starting point, the maximum height, and the maximum distance. Then, after calculating this function, I took a point that was not the vertex. Right? Which is twenty-five thirty. I put it as information in the question and left the strategy up to the reader.*

He added that he used the context of the rocket because it is a simple, low-cost, hands-on experiment that students can do, be inspired by, and "have ideas related to that that you can do." In this way, the teacher created the original statement considering the problem in a different context, highlighting experimentation. It is important to note that the development of creativity is not just limited to mathematical problems but is also applicable in all spheres of life, broadening problem-solving skills and opening up space for new discoveries in all areas of knowledge.

The task presented by the teacher is in line with the official documents (ecological indicator - TDI- Ec1), has clear language and is suitable for the level of teaching it will be

Zetetiké

DOI: 10.20396/zet.v31i00.8672198

used for, in this case, 9th grade, and encourages hypothesizing and argumentation, meeting the epistemic indicators TDI-E1 and TDI-E5, respectively. The task design considers the students' prior knowledge (TDI-C1) without losing focus on going beyond, extrapolating mathematical concepts since it involves a science experiment (TDI-C5).

Promoting tasks with experiments, hands-on, and using manipulable and/or technological materials (TDI-M1), as proposed by Professor OS, can enhance learning by doing, learning in an interdisciplinary way to help understand concepts (TDI-M5). A similar position is defended by Resnick (2020), who argues that practical activities, such as building, playing, and experimenting, allow people to explore their interests and passions playfully and creatively and can also help people to think differently and develop new ideas and solutions to problems.

It is worth noting that applying a "teaching program or a systematic approach to creative problem solving will not guarantee the development of creativity, but only an increase in the likelihood of creativity manifesting itself" (Torrance, 1974, p.3). The commitment of everyone involved is necessary if the learning objective is to be achieved.

Some teachers indicated participation in the course as a professional turning point, whose experience gave them a glimpse of new ways of teaching and learning, as we can see in the testimony of teacher AP (2022) in one of the synchronous meetings:

> *Look, after I started doing the course here with you, I realized how stagnant I was and kept questioning myself. I have never worked like this. I'm actually someone who follows the exercises in the book, and I realized that I have to do things differently from our meetings, which for me has been very thought-provoking because I still don't know how to do this. It's not something I've practiced. So I understand the exercise to move on to another problematic line. I've honestly never done it, but I realize that learning by valuing creativity is more effective.*

Another positive factor of the course highlighted by the teachers was the use of indicators for the analysis, selection, and (re)design of tasks, as reported by Teacher LA, who, in order to (re)design a task, would mainly value the criteria related to the mathematical content which, according to her, would have to be approached in an attractive, fun and inclusive way and the "emotional and affective criteria, stimulating the interaction of the teacher with student, a student with a student with dialog."

Final considerations

This study presents the analysis of creative competence in (future) teachers to (re)design mathematical tasks in the "Training Cycle in Task Design: Quadratic Function and Creativity." The results revealed that few teachers used open-ended tasks, often because they were unfamiliar with them or lacked the time to introduce them into their lessons. The teachers also indicated that they found it challenging to be creative, to design authorial tasks and that when they felt insecure about creating something, they opted to start the creativity process by redesigning tasks.

DOI: 10.20396/zet.v31i00.8672198

Participation in the course showed that to increase confidence in their actions in the classroom, teachers identify continuing education as a way of updating their theoretical and methodological knowledge and resources to use in their practice. In this way, reflection on praxis is continuous since the role of the educator today goes far beyond transmitting information.

According to the participants, the training contributed to the construction and expansion of knowledge about the mathematical object (Quadratic Functions) and the recognition of the development of creativity, of creative mathematical thinking as an essential point in the (re)design of creative tasks. The experience opened space for discussion, evaluation, and diversifying how to approach mathematical content permeated by creativity.

By exploring creativity in the (re)design of tasks, teachers have realized that they can engage their students more effectively, make the learning process more engaging and stimulating, and approach the content more contextualized.

Another point highlighted was in the process of (re)designing creative tasks, in which it is indicated to consider the indicators of the Didactic Suitability Criteria. When creating tasks, teachers should ensure that they are appropriate to the student's level of knowledge and skills, favoring the progressive development of educational competencies. In addition, tasks must be clear and well-structured, avoiding ambiguities or unnecessary difficulties that could compromise the learning process. The assessment of the tasks must also be careful, ensuring that the assessment criteria align with the learning objectives and allow for an accurate analysis of the student's performance.

As a result, it is clear that developing teachers' creative skills are essential for enriching teaching practice and promoting a more dynamic and innovative education. By designing more creative tasks and considering the criteria of didactic suitability, educators can enhance the learning process, making it more meaningful and efficient for students. In this way, valuing creativity in the design of tasks and taking care of their pedagogical suitability contributes to the formation of critical, creative citizens who are prepared to face the challenges of the contemporary world with excellence and confidence. Furthermore, teachers are building a path toward a more dynamic and inclusive education by developing creativity.

However, developing teachers' creative competence is a long-term investment that can generate significant results in the classroom and, consequently, in students' lives.

Acknowledgments

This article is linked to the research projects: The Perspective of the Design of Tasks for the Development of competences in mathematics teachers in the Analysis and didactic intervention of teaching processes (CNPq/2020); The Perspective of the Design of Tasks for the Development of competences in future mathematics teachers to analyze teaching processes and intervene didactically on them (UESB/2022).

DOI: 10.20396/zet.v31i00.8672198

References

Alencar, E. S. (1995). *Como desenvolver o potencial criador: um guia para a liberação da criatividade em sala de aula (*3ª ed.). Vozes. Petrópolis.

Araújo. J. L., & Borba, M. C. (2018). Construindo pesquisas coletivamente em Educação Matemática, In M. C. Borba & J. L. Araújo (Orgs), *Pesquisa Qualitativa em Educação Matemática* (pp. 53-85). Belo Horizonte: Autêntica Editora.

Beghetto, R. A. (2017) Creativity in Teaching. In J. C. Kaufman, V.P.Glăveanu & J.Baer. (Eds), *The Cambridge Handbook of Creativity Across Domains* (pp. 549-564). Cambridge: Cambridge University Press.

Bernadino, F., Gama, W.F.D., & Rezende,V. (2017). *Pesquisas sobre funções afim e quadrática publicadas em periódicos científicos de Educação Matemática.* Encontro Paranaense de Educação Matemática, Cascavel. Available in: http://www.sbemparana.com.br/eventos/index.php/EPREM/XIV_EPREM/paper/viewFile/260/105.

Bogdan, R. C., & Biklen S. K. (1994) *Investigação Qualitativa em Educação: Uma introdução a teoria e aos métodos.* Portugal: Porto Editora LTDA.

Borba, M. C., Malheiros, A. P. S., & Amaral, R. B. (2011). *Educação a Distância online (*3ª Ed.). Belo Horizonte: Autêntica.

Borba, M.C., & Araújo. J.L.(2018). Pesquisa qualitativa em Educação Matemática: notas introdutórias. In M.C. Borba & J.L. Araújo (Orgs.), *Pesquisa Qualitativa em Educação Matemátca* (53-85). Belo Horizonte: Autêntica Editora.

Chizotti, A. (2011). *Pesquisa qualitativa em ciências humanas e sociais* (4ª Ed.). Petrópolis, RJ: Vozes.

Creswell, J. W, & Creswell, J. D. (2021). *Projeto de Pesquisa: Métodos qualitativo, quantitativo e misto.* (Tradução: Sandra Maria Mallmann da Rosa: revisão técnica: Dirceu da Silva 5ª ed.). Porto Alegre: Penso.

Csikszentmihalyi, M. (2014. New conceptions and research approaches to creativity: Implications of a systems perspective for creativity in education. In: M. Csikszentmihalyi *(Ed.), The Systems Model of Creativity: The Collected Works of Mihaly Csikszentmihalyi* (pp. 161-184). Dordrecht: Springer. https://doi.org/10.1007/978-94-017-9085-7.

Ferreira, G.S., & Pires, R.F. (2020). Função Quadrática: Análise dos fenômenos de congruência em atividades realizadas por estudantes do 9º ano do Ensino Fundamental. *Revista Paranaense de Educação Matemática*, 09(20), 485-509. https://doi.org/10.33871/22385800.2020.9.20.485-509

Fiorentini, D. (2003). (Org.). *Formação de Professores de Matemática: Explorando novos caminhos com outros olhares.* Campinas-SP: Mercado de Letras.

Fiorentini, D., & Lorenzato, S. (2012). *Investigação em educação matemática: percursos teóricos e metodológicos* (3ª ed. ver). Campinas: Autores Associados.

Flick, U. (2009). *Introdução à Pesquisa Qualitativa.* Tradução de Joice Elias Costa (3ª ed). Porto Alegre: Artmed.

DOI: 10.20396/zet.v31i00.8672198

Fonseca, M. G. (2015). *Aulas baseadas em técnicas de criatividade: efeitos na criatividade, motivação e desempenho em matemática com estudantes do Ensino Médio.* [Tese de Doutorado em Educação. Universidade de Brasília, Brasília]. https://www.repositorio.unb.br/bitstream/10482/20203/1/2015_MateusGianniFonseca.pdf.

Font, V., & Breda, A. (2015). Competências profissionais na formação inicial de professores de matemática. *Práxis Educacional*, 11(19), 17-34. Available in: https://periodicos2.uesb.br/index.php/praxis/article/view/818.

Freire, P. (2008). *Pedagogia da autonomia: saberes necessários à prática educativa (*37ª ed.). São Paulo: Paz e Terra.

Godino, J. (2009). Categorías de análisis de los conocimientos del profesor de Matemáticas. *Revista Iberoamericana de Educación Matemática*, 20, 13-31. Available in: https://www.ugr.es/~jgodino/eos/JDGodino%20Union_020%202009.pdf.

Godino, J. D., & Batanero, C. (2009). *Formación de Profesores de Matemáticas basada em la reflexión guiada sobre la práctica.* Conferência CIBEM. Puerto Montt, Chile. https://www.ugr.es/~jgodino/eos/fprofesores_reflexion_guiada_22dic08.pdf.

Godino, J. D., Batanero, C., & Font, V. (2008). Um enfoque onto-semiótico do conhecimento e a instrução matemática. *Acta Scientiae* - Revista de Ensino de Ciências e Matemática, 10 (2), 07-37. Available in: http://www.periodicos.ulbra.br/index.php/acta/article/view/62.

Gonçalves, F. B. (2019). *Uma sequência didática para o ensino de Função Quadrática.* [Dissertação de Mestrado Profissional em Ensino de Matemática, Universidade do Estado do Pará (UEPA)], Belém. Available in: https://educapes.capes.gov.br/bitstream/capes/559514/1/F%C3%A1bio%20Barros%20Gon%C3%A7alves.pdf

Gontijo, C. H. (2007). *Relações entre criatividade, criatividade em matemática e motivação em matemática de alunos do ensino médio.* [Tese de Doutorado em Psicologia. Universidade de Brasília, Brasília]. Available in: https://repositorio.unb.br/bitstream/10482/2528/1/2007_CleytonHerculesGontijo.PDF

Gontijo, C. H., & Fonseca, M. G. (2020). *Criatividade em Matemática: lições da pesquisa*. Curitiba: CRV.

Gontijo, C. H., Carvalho, A. T de, Fonseca, M. G., & Farias, M. P. (2019). *Criatividade em matemática: conceitos, metodologias e avaliação.* Brasília: Editora Universidade de Brasília.

Gontijo, C. H., Silva, E. B., & Carvalho, R. P. F. (2012). A criatividade e as situações didáticas no ensino e aprendizagem da matemática. *Linhas Críticas,* 18 (35), 29-46. https://doi.org/10.26512/lc.v18i35.3839.

Gusmão, T. C. R. S. (2006). *Los procesos metacognitivos en la comprensión de las prácticas de los estudiantes cuando resuelven problemas matemáticos: una perspectiva ontossemiótica*. [Tese de Doutorado em Didáctica de las Matemáticas. Faculdade de Ciências da Educação, Universidade de Santiago de Compostela, Espanha]. Available in: http://enfoqueontosemiotico.ugr.es/documentos/Tesis_doctoral_Tania_Gusmao.pdf

DOI: 10.20396/zet.v31i00.8672198

Gusmão, T. C. R. S., & Font, V. M. (2020). Ciclo de Estudo e Desenho de Tarefas. *Educação Matemática Pesquisa*, 22 (3), 666-697. https://doi.org/10.23925/1983-3156.2020v22i3p666-697.

Gusmão, T.C.R.S. (2019). Do desenho à gestão de tarefas no ensino e na aprendizagem da Matemática. In: *Anais do XVIII Encontro Baiano de Educação Matemática*. Ilhéus, Bahia. XVIII EBEM. Available in: https://casilhero.com.br/ebem/mini/uploads/periodico/files/2019/PA2.pdf.

Hummes, V. B., Font, V., & Breda, A. (2019). Uso Combinado del Estudio de Clases y la Idoneidad Didáctica para el Desarrollo de la Reflexión sobre la Propia Práctica en la Formación de Profesores de Matemáticas. *Acta Scientiae*, 21(1), 64-82. https://doi.org/10.17648/acta.scientiae.v21iss1id4968.

Kaiber, C. T., Lemos, A. V., & Pino-Fan, L. R. (2017). Enfoque Ontossemiótico do Conhecimento e da Instrução Matemática (EOS): um panorama das pesquisas na América Latina. *Perspectivas da Educação Matemática*, 10 (23), 531-552. https://periodicos.ufms.br/index.php/pedmat/article/view/5056.

Kattou, M., Christou, C., & Pitta-Pantazi, D. (2016). Characteristics of the Creative Person in Mathematics. In G. B. Moneta & J. Rogaten (Edts.). *Psychology of creativity: Cognitive, emotional, and social processes* (pp.99–123). New York: Nova Science Publishers.

Kieran, C. (1992). The Learning and Teaching of School Algebra. In D. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 390-419). New York: Macmillan Publishing Company.

Maia, D. (2007). *Função Quadrática: Um estudo didático de uma abordagem computacional*. [Dissertação de Mestrado em Educação Matemática. Pontifícia Universidade Católica de São Paulo, São Paulo]. Available in: https://tede2.pucsp.br/handle/handle/11133

Marques, A. S., Andere, A., Silva. P. S., & Caldenucci, T. L. H. (2021). *Matemática: Ensino Fundamental – Anos Finais (9º Ano Livro 2)*. São José dos Campos: Editora Poliedro.

Ministério da Educação (2018). *Base Nacional Comum Curricular (BNCC)*. Ministério da Educação, Brasília.

Ministério da Educação (2019). Resolução do Conselho Nacional de Educação (CNE/CP) de 20 de dezembro de 2019. Define as Diretrizes Curriculares Nacionais e institui a Base Nacional Comum para a para a Formação Inicial dos Professores para a Educação Básica (BNC-Formação). Brasília: Ministério da Educação, Brasília.

Moreira, C.B. (2017). *O desenvolvimento da percepção de espaço na criança da educação infantil: o papel das tarefas*. [Dissertação de Mestrado em Educação Científica e Formação de Professores. Universidade Estadual do Sudoeste da Bahia – UESB. Jequié]. Available in: http://www2.uesb.br/ppg/ppgecfp/wp-content/uploads/2017/08/CELMA-MOREIRA-2017-1.pdf

Ninow, V., & Kaiber, C.T. (2016). *Enfoque Ontosemiótico: Uma análise do conceito de função.* XII Encontro Nacional de Educação Matemática. Available in: http://www.sbembrasil.org.br/enem2016/anais/pdf/7701_3544_ID.pdf.

Pereira. L. S. A. (2019). *A gestão de tarefas matemáticas por professoras dos anos iniciais do ensino fundamental.* [Dissertação de Mestrado em Ensino. Universidade Estadual do

DOI: 10.20396/zet.v31i00.8672198

Sudoeste da Bahia (UESB)]. Available in: http://www2.uesb.br/ppg/ppgen/wp-content/uploads/2019/09/Disserta%C3%A7%C3%A3o-Lindomar-Fomatada.pdf.

Resnick, M. (2020). *Jardim de Infância para a vida toda: por uma aprendizagem criativa, mão na massa e relevante para todos.*(2020). Tradução Mariana Casseto Cruz e Lívia Rulli Sobral; revisão técnica Carolina Rodeghiero e Leo Burd. Porto Alegre: Penso.

Rodrigues, G. S. S. (2019). *Desenho de tarefas matemáticas na perspectiva da criatividade: um estudo com professores.* [Dissertação de Mestrado em Ensino. Universidade Estadual do Sudoeste da Bahia. Vitória da Conquista].
Available in: http://www2.uesb.br/ppg/ppgen/wp-content/uploads/2020/02/DISSERTACAO-GICELIA-24-01-2020-1.pdf.

Silva, H. L. (2019). *Função quadrática: Investigar os conhecimentos que alunos do 1º ano do ensino médio apresentam para lidar com questões que envolvem os principais conceitos associados à função quadrática.* [Dissertação de Mestrado Profissional em Matemática em Rede Nacional – PROFMAT. Universidade do Estado do Rio de Janeiro, Instituto de Matemática e Estatística]. Available in: https://www.bdtd.uerj.br:8443/handle/1/4835.

Sousa, J.R. (2018). *(Re)desenho de tarefas para articular os conhecimentos intra e extramatemáticos do professor*. [Dissertação Mestrado em Educação Científica e Formação de Professores. UESB, Jequié].
Available in: http://www2.uesb.br/ppg/ppgecfp/wp-content/uploads/2019/10/SOUSA-Jorge-Ramos-de.-Mest.-Educ.-UESB_2018.pdf.

Teixeira, P. M. M, & Megid Neto, J. (2017). Uma proposta de tipologia para pesquisa de natureza interventiva. *Revista Ciência e Educação,* 23 (4), 1055-1076. https://doi.org/10.1590/1516-731320170040013.

Torrance, E. P, & Torrance, J.P. (1974). *Pode-se ensinar criatividade?* São Paulo: EPU.

Yin, R.K. (2016). *Pesquisa qualitativa do início ao fim* (Tradução: Daniel Bueno; revisão técnica: Dirceu da Silva). Porto Alegre: Penso.