Developing Computational Thinking and Reading and Writing Skills through an Approach for Creating Games

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***Abstract*— Research and full paper. Digital games are increasingly a part of our daily lives and are already considered teaching and learning tools. However, its production and documentation is a very complicated task that requires programming skills and knowledge from different areas. This has hampered the development of games in the classroom environment. On the other hand, some teachers have proposed this activity to enable their students to learn school content in a more meaningful way and, consequently, improve learning rates. An alternative for the adoption of game-based learning is an unplugged approach for creating games based on natural language, in which students learn the fundamentals of computing in a playful way and without the use of computers. In this context, this article presents an approach that proposes the creation of games in an unplugged way by using texts produced by students, thus favoring the development of computational thinking and reading and writing skills in the classroom. Also, it may support the students' interest in the computing area by motivating them to enter a higher education course or pursue a career in that area. The results of the exploratory study show that the proposed approach can favor the development of computational thinking, as well as motivate the production of texts, developing students' reading and writing skills, therefore contributing to the improvement of learning assessments.**

Keywords—computational thinking, reading and writing skills, game design, unplugged

I. INTRODUCTION

The increasingly strong presence of digital technologies in our daily lives has facilitated access to knowledge and the opening of new educational possibilities. Some schools and universities have adopted the use of these technologies, especially game-based learning, as a way to help their students learn more significantly and develop skills and abilities related to technology and computing, especially computational thinking [5, 50, 51, 52, 53, 54, 55, 56, 57, 58].

Some educators have also been more interested in educational games. They have discovered the potential of using digital games in the classroom environment [17] and feel that they can boost their students' learning process through the use and creation of games [14, 12, 16].

For Byrne [11], it is possible to extrapolate the use of games in education. His studies show that teachers and students can get involved in game production projects in the school. The results show excellent gains in learning, cognitive development, creativity increase, and student autonomy, not to mention that it makes it possible to know a specific computational domain. According to Barr [6], teachers make their classes more exciting and meaningful for students who, by being motivated to develop games, learn the contents of several curricular components involved in the project, thus configuring it as an interdisciplinary activity.

The production of a game starts with the conception of its idea and the specification of its requirements, which is called Game Design. Specifying a Game Design is a process that involves creativity, imagination, writing activities, and communication. Game Design documents are often difficult to understand, lacking information, and with inconsistencies. They are usually presented in written form and do not provide clarity to inexperienced people. If this activity is not well executed, it can generate inaccuracy of information, conceptual errors, and poorly collected data as a result of the misunderstanding, which may hinder the game's development phase [15]. Thus, this activity has the playful appeal of games and a challenging potential in terms of writing skills.

Some tools that use visual programming have helped teachers and students to develop digital games, such as e-adventure [16, 7], Scratch [10], Alice [9, 18], and The Hour of the Code [19]. However, there are few initiatives that propose the specification of a game's Game Design by students and teachers [8, 59, 60, 61]. In addition, students still have difficulties in the development of reading and writing skills, often evidenced in text production activities. Historically, the results of the assessments of primary education have shown deficiencies not only in mathematics, but also in text production [13, 4]. In other words, there is a research gap concerning technology strategies to contribute to the development of reading and writing abilities [1, 2].

The production of games in the classroom environment can favor the development of computational thinking since the students need to think about the problems related to the game, its decomposition, the construction of algorithms to solve the problems, and the identification of characteristics

that are common to the issues and their solutions. An innovative variation of that approach could be adopting game-based learning in an unplugged way for creating games based on natural language, in which students learn the fundamentals of computing in a playful way and without the use of computers.

In this context, this article presents an approach that proposes the creation of games by students and teachers in the classroom environment in an unplugged way, using textual production. We applied this approach through an exploratory study involving higher education students.

To present the details of this work, we organized the rest of this document as follows. Section II presents the theoretical foundation and Section III the Creative Game approach. Then, Section IV shows an exploratory study using the proposed approach. Finally, Section V highlights our final considerations about this work.

II. THEORETICAL FOUNDATION

This section presents the main subjects related to the research topic.

A. Computational Thinking

Currently, there have been frequent discussions about the development of computational thinking as one of the essential skills of the modern world. This need is due to the rapid technological evolution and its insertion in the various areas of knowledge. It is difficult to imagine a society without computers, mobile devices, and related technologies. Thus, computer knowledge must be included in the primary education of a citizen.

Originally Wing [36] conceptualizes computational thinking as a way of thinking and finding solutions to everyday problems using the fundamentals of computing and mathematics. According to the author, computational thinking is a basic skill, such as reading, writing, speaking, and performing mathematical operations.

According to Brackmann [37], "computational thinking is the distinctive creative, critical and strategic human capacity to know how to use the fundamentals of computing in the most diverse areas of knowledge, in order to identify and solve problems collaboratively through clear steps, in such a way that a person or a machine can execute them effectively." That is, using the concepts of computing to solve everyday problems.

Thus, as Wing [36] argues, we understand computational thinking as a skill for everyone, which means that it does not consist of an area of knowledge restricted to computer professionals.

Therefore, we suggest the game-based approach, the concept of which we present in the paper as one of the strategies for working with computational thinking in the classroom environment.

B. Game Design

The process of producing a game starts with the definition of its initial concept (Game Design), and it ends with the creation of a final version of the game, with several intermediate steps. In the Game Design elaboration stage, the game's main idea, style, target audience, narrative, mechanics, characters, scenarios, objectives, phases, difficulty levels, sounds, among other aspects, are defined [43].

Game Design is the process of creating the content and rules of a game - the goals that the player will feel motivated to achieve and the rules that he or she will need to follow as if making significant decisions to overcome the challenges proposed [44].

For Adams and Rollings [45], the Game Design is the essence of a game. It is where the way the game works is defined and where its elements are described. It is usually elaborated with the participation of different professionals from the team that will produce the game for a particular type of audience of players.

The result of the Game Design is the Game Design Document (GDD), which must contain all the definitions, requirements, and rules of the game. One can define the GDD as "a document that describes the characteristics" of the Game Design "in detail" [46].

The GDD is a textual production that serves as a reference for everyone involved in the development of the game, thus keeping everyone connected to the same goals [47]. Generally, it has a chain structure of several elements of the game: the concept of the game; game mechanics; user interfaces; the static, animated and video graphic components; the description of characters; the plot and the story; sounds and music; the detailing of levels (phases), among other elements. Through these elements, it is possible to describe what a game must have; however, due to such detail, this document can have from tens to hundreds of pages [48].

We can understand the Game Design as a complex process, which allows the visualization of the whole set of work to be carried out by the game production team [49].

When it comes to digital educational games, the Game Design must also consider pedagogical aspects such as the description of the pedagogical content, the definition of the learning objectives, the specification of how the student will be evaluated, what skills will be developed, among others.

Thinking about taking the Game Design production process of an educational game to the classroom environment is imagining different learning possibilities, considering that it involves different knowledge that may be related to the curricular contents. Another essential aspect is the participation of the educator as an articulator and facilitator of the development of the activities involved in the production of an educational game.

C. Game-based Learning

Educational games, especially digital ones, can be considered learning objects that, when used in the classroom environment, allow the students to live an immersive and motivating experience. Digital games, by enabling simulation in virtual environments, provide precious moments for exploring various contents and developing computational thinking. It is one of the reasons that make digital educational games a great success when used in favor of learning. Therefore, they are educational resources that subsidize a new type of education based on digital technologies.

Digital games can be a fun and effective way to learn the most diverse content. It is a fantastic resource not only for

school learning but also for different types of institutional training [38].

When thinking about new learning strategies, one should also consider the development of games by students and teachers in the classroom environment. The act of developing a game allows the students to acquire computational skills and explore content in a more meaningful way. According to Berry [39], it encourages students to participate more and more in the construction of their knowledge, offering them the opportunity to be active elements in the learning process.

In this context, one can conceptualize game-based learning as a strategy that uses the game as a tool for students to engage in learning while playing [40].

Thus, games have educational potential, are engaging, allow users to test in an artificial environment, and awaken in the players the constant effort to be better. Also, they have the advantage of allowing users to perform actions in a simulated practice [41].

However, the absence of high-level tools and support for teachers and students to create games hinders those who wish to adopt this innovative approach for learning [42]. Thinking about possibilities for creating and using games in an unplugged way becomes a solution to make game-based learning feasible, even in contexts that lack technological devices.

D. Unplugged Approach

Computer science and its sub-areas have benefited from the unplugged approach, in which its concepts are taught without using computers. Unplugged activities are performed through kinesthetic and collaborative activities in which the concepts of computer science are learned [28]. The first initiative in this regard was published by [30], in a book containing suggestions for activities for teachers and students.

According to Curzon [31], unplugged computing aims to encourage people to understand the concepts of computing in a playful way and without requiring the direct use of the computer.

Thus, the unplugged approach can be applied anywhere since it is not necessary to use hardware and software resources [32]. For Bell [33], applying activities with content aimed at the computing area without using a computer ensures that students see the computer as a study tool.

According to Feaster [34], unplugged computing focuses on better understanding the technology without using it. In this process, the student must think like a computer, which makes learning more challenging and fun.

The unplugged activities are directly connected to computational thinking, which tends to modify the way individuals (disregarding age limits) solve problems, contributing to the creation of new tools. It happens because individuals tend to become technology producers, interested in the operation of technology, not just mere consumers [35].

III. CREATIVE GAME APPROACH

The general idea of the approach proposed in this work, called Creative Game (CG), is to promote the development of the students' computational thinking and reading and writing skills through the development of games in an unplugged way. The approach has a process for developing a game from a textual production that describes its narrative, and the elements and functionalities needed for its gameplay definition. The text produced is the Game Design, which is written informally, according to the writing ability of the students and the teacher's guidance. The next sections describe the Creative Game process, highlighting is target audience, materials used and activities exiting in the process.

A. Target audience

The approach is proposed to be used by teachers and students of different educational levels. The primary education is a period in which the students' writing and reading skills are more intensively developed, so the use of Creative Game can be very appropriate. Also, the use of the approach in primary school helps to develop computational thinking skills from an early age, as well as to attract students to the areas of computing and digital games development.

Also, the proposed approach can also be used in high school or higher education. Teachers of computing courses can use the approach in classes related to computational thinking, game development, and textual production.

B. Materials

The Creative Game approach includes the following support materials: teacher's guide, student's guide, and objects catalog, which are detailed below.

Teacher's guide. This guide aims to assist the teacher in understanding the concepts related to game development and in applying the approach proposed. It has a description for each activity of the Creative Game process, which is represented in Fig. 1. The use of this guide is essential since not every teacher knows about computing or, more specifically, games. The guide also provides recommendations for the teacher in terms of developing language and computational thinking skills.

Student's guide. This guide contains specific tips and guidelines for students to produce their games. The guide is used for guidance purposes, presenting possibilities and possible decisions that students may have regarding the production of their games. It also offers a step by step guidance to produce the game with illustrative examples.

Objects Catalog. This document contains different images of elements (objects, characters, scenarios, and actions) that can help students to compose their games. The catalog aims to assist the creative process of idealizing the game. Other approaches, such as the Scratch Object Model, already use this type of catalog [29].

C. Activities

In a nutshell, the approach proposed consists of a set of 10 activities according to the process illustrated in Fig. 1. The teacher and his or her students can perform the process as extra-class activities, or the teacher can integrate it into the planning of curricular subjects over a defined period. The duration of the process will depend on the availability to hold one or more weekly meetings and the evolution of the accomplishment of each task in the process.

Each of the activities shown in Fig. 1 is described next.

Presenting the activity. Initially, the teacher shows the work proposal to the students, indicating the objective

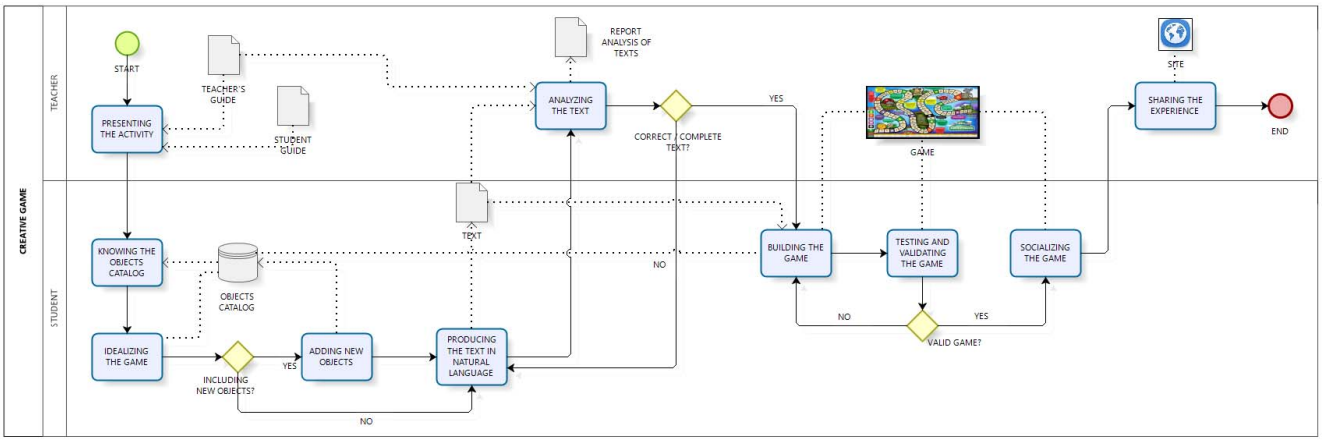

Fig. 1. The Creative Game Process.

(building a game) and explaining concepts about Game Design. The teacher can present classic games and their Game Designs, thus enabling a better understanding of these concepts.

The teacher should present the student's guide and objects catalog to the students. We also recommend that the teacher presents the timetable for the application of the Creative Game process, as well as how he or she will evaluate the students during the process. The teacher should also present possible restrictions on themes and types of games that students must develop, which will depend on the teacher interest and planning.

Knowing the objects catalog. The objects catalog consists of printed cards containing images of characters, objects, actions, and scenarios that students can use in the elaboration of the game. Students should manipulate the cards as a form of inspiration for structuring the idea and elements of the game. If necessary, students can add items to the catalog through drawings made by themselves (***Adding new objects***).

Idealizing the game. This activity consists of the discussion and initial design of the game. Students involved in the project must meet and decide about the characteristics of their game. The result of this activity is the first draft of the text, which contains a brief description of the functioning of the game to be developed. Both the student's guide and the objects catalog can be used to promote the process of discussion and ideation of the game. We recommend that the teacher verify if the game proposal is consistent with the objectives and restrictions presented, approving, rejecting, or indicating the necessary corrections. It prevents any project from having to be redone or being discarded after other tasks are completed.

Producing the text in natural language. In this activity, students will write a document in natural language, specifying the idea of the game. The text must present the story, scenario, characters, rules, and other elements of the game. These are the common elements present in most Game Design Documents used in industry and the academy [20, 21, 22, 23, 24, 25, 26, 27]. Whenever appropriate, students can use the elements presented in the objects catalog. The structure of the document, formal or informal, must be decided according to the interests and planning of the teacher.

We believe that at this stage, students will have the opportunity to develop the ability to express ideas clearly and to exercise writing skills in a playful and enjoyable way. The idealization of their own game can configure as a motivational factor for their textual production.

Analyzing the text. The analysis of the documents produced by the students must be performed by the teacher, who will be attending to the adequacy of the writing (norms of the language), and verifying if it contains the description of the elements and the rules needed to understand how the game works. The feedback from this stage can lead to the students rewriting the text with the necessary adjustments, an activity that they can perform individually or in groups, at the teacher's discretion.

We believe that writing and rewriting the text can favor the development of reading and writing skills, considering that, at that moment, students have the opportunity to review their documents and make the necessary adjustments to improve their textual production, through the guidance received from the teacher. During the process of idealizing the game and writing the text, students will also naturally explore skills related to computational thinking, since they systematize their ideas and shape rules for the game's behavior (state of the game, conditions to be observed, expected results, among others). For example, students explore abstraction and decomposition skills when establishing the problem of the game and the line of reasoning to solve it, decomposing the solution into smaller parts (phases of the game) and working on each one individually and, later, in an integrated way.

Building the game. In this phase, the students reread the text, select the necessary elements and build the game using the different materials available at the school (different papers, boxes, paint, polystyrene foam, scissors, glue, clay, among others). We recommend that the teacher assist students in planning the construction of the game, including listing and selecting the necessary materials. Since it is an unplugged approach, it is possible to apply it in any space, even if it does not have computers.

Testing and validating the game. This activity is an opportunity for students to play and test their games. We recommend that the teacher help students to check for possible flaws in the rules or lack of elements of the game. It is essential to guide the last adjustments necessary for the game and the text.

Socializing the game. With the games tested and validated, the teacher provides the class with a round of games in which students can experience the games created by their colleagues. In this stage, students can express their opinion about their colleagues' games, checking if they are engaging, fun, and attractive.

Sharing the experience. In the end, the whole experience carried out using the Creative Game approach can be shared with other educators inside and outside the school space.

IV. Exploratory Study

This section presents an exploratory study on the use of the Creative Game approach presented in the previous section. The study sought to understand the phenomena observed during the application and the results of the proposed activities [32, 33].

The exploratory study was divided into two stages: application of the approach and evaluation and analysis of the results.

We carried out this study as an extra-class activity. It involved the participation of 22 students of higher education courses such as computing, information systems, and pedagogy. Also, the study was conducted by a teacher with experience in improving reading and writing skills. We report the details on the planning and execution of each step of the study below.

A. Application of the Approach

In this stage, students had the opportunity to use the Creative Game approach. Initially, the teacher explained the purpose of the activity and spoke about the concept of games and game development, specially the role of the Game Design. She showed the elements that are indispensable for the elaboration of a game, such as a plot, the characters, the scenario, the rules, among others (***Presenting the activity)***.

The teacher divided the class into five teams and distributed a kit from the objects catalog to each one of them. She explained that the catalog is a collection of printed cards containing images of characters, objects, actions, and scenarios that should be used in the creation of the idealized games.

The students learned about and manipulated the cards as a form of inspiration for structuring the idea and the elements of the game, as illustrated in Fig. 2 (***Manipulating the objects catalog***). Some students produced new items for the objects catalog (***Manipulating the objects catalog***).

Fig. 2. Students manipulating the objects catalog.

Then, the teams started to idealize the game. The students socialized the game project orally within the group while manipulating the cards under the chosen scenario. They explained where it would take place, which characters would appear, what would be their actions, and what tasks and challenges should be overcome (***Idealizing the game***). After this stage, they made the written record of the game, considering what was structured (***Producing the text in natural language***).

The text was continuously revised to favor the record's clarity regarding the game's functioning and to adapt the writing to the norms of the language. When they noticed a lack of elements, the students returned to the text to make the necessary adjustments. This step was performed with the help of the teacher, who advised students on aspects to improve the text produced, such as orthographic adjustments, structuring of paragraphs, or related to the complement of the information needed to understand the game (***Analyzing the text***), as seen in Fig. 3.

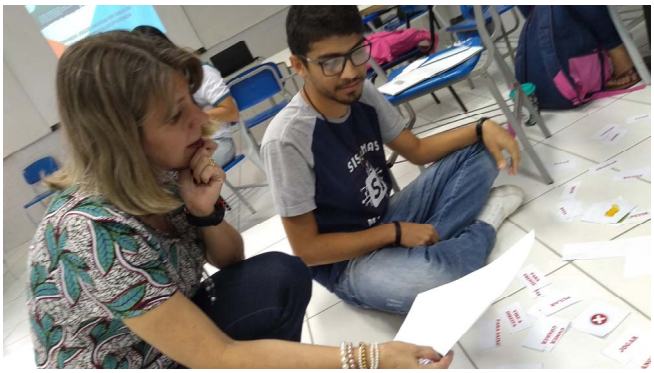

Fig. 3. Teacher analyzing the text.

After these steps were completed, each team started the materialization of the game using the cards selected in the objects catalog and other materials that they brought to class. Each team built its own game in an unplugged way. All of the games produced were board games, with moving objects and challenges to be overcome (***Building the game***).

The next stage was the testing and validation of the game by the team itself. The students tried out the game and corrected the flaws found (***Testing and validating the game***).

Finally, the teams presented their games to the class. The socialization stage included a round of games in which each group had the opportunity to try all of the games produced (***Socializing the game***).

B. Evaluation and analysis of the results

The second and last stage was the evaluation and analysis of the results. This evaluation used as data source the observation of the study by a researcher, the opinion of the participants (teacher and students), and the material produced by the students (texts) and by the teacher (analysis of the texts).

In this sense, the researcher interviewed the students and the teacher to analyze qualitatively the materials produced, the strategy proposed, and its potential impact on student learning. The results are described next.

1) Considerations Regarding the Idealized Games.

Regarding the idealized games, it is clear that there is no limit to the students' imagination. We verified how the students are familiarized with games, facilitating the elaboration of the games' idea from the identification of characters, scenarios, and rules to the change of levels, scoring, and overcoming challenges. The students had the opportunity to use their previous experience as players to propose games that they were interested in playing.

It was possible to observe that the number of elements in the objects catalog represents a factor that limits creativity for the elaboration of games. However, the opportunity for students to expand the catalog by developing new elements helped to overcome this limitation.

The students produced five board games. According to the teacher, one team developed the game exactly as planned; three added new elements throughout the development, expanding the initial planning of the game; and one was unable to complete the game as expected, which ended up being incomplete. We noticed that all of the games had more elements of Game Design than the team wrote in its texts.

2) Considerations Regarding the Textual Production

The written record of the description of the elements and functioning of the games was an essential activity so that students could systematize their ideas and better structure their games. They put their writing skills into practice, motivated by the interest in creating a product.

Revisiting the text, verifying its completeness, and correcting the writing allowed students to get to know and improve the knowledge related to textual production in a meaningful and playful way. In the study, we could verify the students' difficulty in developing clear texts, containing all the information necessary for the game. In addition, the teacher had to intervene so that the documents were not too short, missing relevant information.

We can consider this textual production as a Game Design Document (GDD) elaborated with less complexity and formality, but with similar information like traditional GDD, and without requiring lots of technical skills in computing.

After adjustments and rewriting the texts, it was possible to observe the existence of the description of the main elements of the Game Design. Everyone was able to describe the scenarios and characters of the games. They also presented some rules. Thus, it was possible to extract the main features of the games and instantiated them.

The teacher could see that when producing the texts, students developed some computational thinking skills, such as algorithmic thinking. Note that in the following excerpt, extracted from the game "The Village and adapted by educators," students describe rules (step by step) for the player to overcome an obstacle, as a kind of algorithm obtained from the text.

"The prince must run through the maze until he reaches the princess. Along the way, stones will appear, which the prince must jump over. If the prince hits the stone, he will lose one life. If there are no more lives, the game is over".

```
Start
Life = 3
Prince (maze, run)
While the prince does not arrive at the princess do
   Stones appear
   Prince (stone, jump)
   If prince hits the stone then
        Life = life -1;
   End if
   If life = 0 then
        End of game
   End if
End while
End.
```

3) Considerations Regarding the Strategy Proposed

After conducting the experience reported, we were able to verify that the strategy of creating games from natural language is an alternative for adopting game-based learning, which can develop computational thinking and writing skills.

Computational thinking skills are worked on when students think about the problem of the game, its decomposition, the algorithms with the rules, the change of phases, and the overcoming of challenges.

According to the teacher, the approach favors skills related to natural language, specifically text production, since it is necessary to use reading and writing to elaborate on the Game Designs. The proposed strategy is a practical, motivating, playful, and meaningful activity for the development of these skills, even in an older audience, from which we could expect less excitement with the proposal.

The students reported that the approach motivated them to write and that specifying the elements of the game in a text makes it easier to materialize it.

V. FINAL CONSIDERATIONS

Several pieces of research have shown positive experiences of game-based learning. However, there are only a few strategies for game development by non-specialists. The proposal presented in this work encapsulates the technical aspects of Game Design, making the development process more natural for teachers and students in the classroom environment, thus contributing to the adoption of game-based learning.

This solution can collaborate for students to acquire the necessary knowledge for the development of technology and computing skills needed for the formation of computational thinking, as well as reading and writing skills in natural language.

Thus, we can conclude that the Creative Game approach can contribute to stimulating the interest of students in the computing area since it uses concepts of game development and solution of problems involving technology.

As a future study, we will apply the proposed approach with children in the fifth grade of elementary school. We understand that this is a phase in which writing skills are beginning to improve and that it has the potential to attract the students' attention to computing from an early age. With this, we will be able to verify if we will have positive results with children in terms of computational thinking, reading and writing skills, and interest in computing.

As future work, we also intend to automate the game production process so that a computational tool can interpret the texts produced by the students and generate digital prototypes using natural language processing techniques.

ACKNOWLEDGMENT

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, by a scholarship under the Capes-Print program, process 88887.370174/2019-00, and by INES 2.0, FACEPE grant APQ-0399-1.03/17, CAPES grant 88887.136410/2017-00, and CNPq grant 465614/2014-0.

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