Practical Guide for Designing Activities that Integrate Curricular Content, Computational Thinking and Constructionist Theory*

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Abstract. *This paper presents a practical guide to encourage professionals to reflect on aspects that must be considered for the elaboration of a didactic activity that integrates: a) promotion of curricular learning; b) development of Computational Thinking; and c) a constructionist learning environment. A proof of concept shows that the guide has the potential to instigate teachers of k-12 education in the development of activities with the proposed characteristics.*

1. Introduction

The Computational Thinking (CT) theme was placed in evidence from an essay written by J. Wing [Wing 2006]. For some researchers [Lee et al. 2011, Valente 2019], the CT can be considered a method for solving problems, based on Computer Science concepts, which can promote competencies that are considered fundamental for the 21st century. Therefore, it is believed that involving people with CT can stimulate the development of some mental tools such as, the ability to deal with or develop abstractions, the algorithmic thinking, the generalization of solutions, the identification of patterns, among others.

Nonetheless, challenges are faced by teachers in bringing CT into their practice, as limited CT teaching expertise [Israel et al. 2022]. In order to help to overcome this issue, this article proposes a practical guide that aims to help and guide teachers in the design of activities that foster some of the mental tools of the CT [Wing 2006, Wing 2014], allowing students to use them in solving problems of different natures. The instrument also aims to provide a look on how to conduct the proposed activities in class, trying to instigate the teacher to plan the construction of artifacts that are meaningful to students.

Several works [Saad and Zainudin 2022, Tsai et al. 2021, Martinelli et al. 2019, Souza and Nunes 2019, Yadav et al. 2017, Angeli et al. 2016, Csizmadia et al. 2015] have already explored the integration of the CT in k-12 education, many of them aimed at helping and training teachers. Angeli et al. (2016) proposes a generic structure to help design curricula for the elementary level, exploring teachers education through Scratch. Martinelli et al. (2019) proposes an approach that brings a set of recommendations that can be applied to the development of activities that encourage the CT in the early years of elementary school. Other approaches can be found in systematic

*This work was carried out with the support of CAPES - Brazil - Financing Code 001, the SACCI Network, SMED/Pelotas, PREC and PRPPG / UFPel.

reviews/mappings [Saad and Zainudin 2022, Souza and Nunes 2019, Bordini et al. 2017, Ortiz and Pereira 2018, Rodrigues et al. 2018]. This work, in turn, aims to assist teachers in designing activities that involve the development of CT skills while promoting curricular learning. It differs from the previous ones due to a supporting material and a set of guiding questions, based on CT and constructionist theory concepts and rubrics, which lead teachers in the creation of activities. The practical guide provides flexibility to support different CT concepts and pedagogical approaches for any level of k-12 education.

It should be noted that in several teaching-learning processes, which involve problem-solving and learning curricular content, naturally some CT skills are required and addressed. Involuntarily, teachers already develop several of these skills, even without this perception. An important aspect is the perspective of being able to demonstrate, to give visibility and awareness of these competencies to the actors involved. In other words, to show how the concepts of the CT are inserted in these processes and to encourage their approach with greater emphasis, so that they become part of an arsenal of mental tools for future problem-solving. The article is organized as follows. Section 2 describes the theoretical foundation and design methodology of the guide, as well as its components. Section 3 proposes a method for its use and in Section 4 the execution of a proof of concept [Neto et al. 2018] is detailed. Final considerations are outlined in Section 5.

2. Practical guide for designing activities

The practical guide proposes to guide teachers in the design of activity plans which have, simultaneously, the following goals: a) to promote curricular learning; b) develop CT skills; and c) provide a constructionist learning environment, which encourages learners to be protagonists of their learning from the construction of significant artifacts. In this way, the guide aims to implement an instructional learning model. According to [Chanthala et al. 2018], such approach can facilitate the translation of a theory into something that can be more easily included in the planning of an educational activity.

In order to design the practical guide, we chose to adopt the Design-Based Research (DBR) method [Reis and Amiel 2019, Collins 1992, Brown 1992, Matta et al. 2014] due to the following reasons: it has an interventionist focus; it is suitable for the development of proposals in educational contexts; it recommends developing the project through iterative design cycles. The DBR cycle applied in the guide creation process consisted of the following steps: proposition of the instructional model, implemented in cards, based on the constructionist theory and on the concepts of CT; proposition of activities by teachers based on the instructional model; evaluation of the proposed activities from previously proposed rubrics; re-design of guide cards based on the results.

In this project, the instructional model adopts: a) the Papert (1980) constructionist theory, especially considering the dimensions (pragmatic, semantic, syntonic, syntactic, and social) organized by Maltempi (2004), where a new subject is not transmitted, and the student becomes the protagonist of his knowledge; b) the CT as a problem-solving process which includes, in this proposal, the concepts of abstraction, decomposition, generalization, algorithmic thinking and evaluation, anchored in the studies of Selby and Woollard (2013); and c) the scope of a curriculum content for k-12 education.

The practical guide has a strategy of using questions to encourage the professional to reflect on the various aspects that must be considered for the elaboration of a didactic

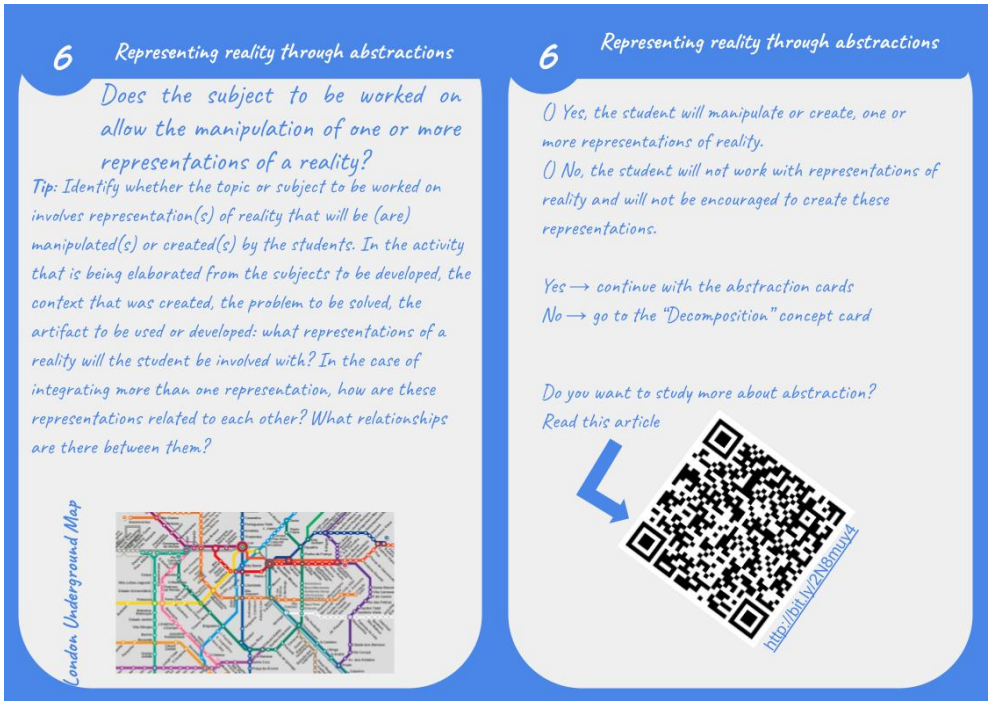

Figure 1. Example card with questions to generate didactic activities. Source: Authors

activity, especially inspiring the inclusion of characteristics that promote constructionist dimensions and/or concepts of computational thinking. It is organized in the form of cards, for a total of 29, with one of them illustrated in Figure 1.

Due to space limitations, the set of cards is available at `https://bit.ly/3BCoBlE` and its sequence of use is illustrated in Figure 2. The first 4 cards, in orange, refer to the identification of a curricular content, the specification of a problematization to be worked on, the characterization of the context, and the identification of possible artifacts to be involved. The following 22 cards aim to instruct and instigate the teacher to include the concepts of the CT in his proposal, in particular, abstraction, decomposition, generalization, algorithmic thinking and, evaluation. The last 3 cards, identified by constructionism, instigate the insertion of the pragmatic, syntonic, semantic, syntactic and social dimensions of constructionism. For each of the concepts, initially an intuitive and, practical characterization of the same is presented, making available through external links a series of materials that allow (if desired) to deepen the theme. Then, a sequence of questions stimulates reflection and induces the description of possibilities for integrating the development of the concept with the curriculum content. The questions not only induce the incorporation of concepts but cover various levels of approach to them. These levels were based on previously proposed rubrics: CT rubric and constructionist rubric[1].

The cards related to each concept follow the same organizational structure. The first one, illustrated in Figure 1, introduces the concept (abstraction in this case) and identifies the possibility of its integration in an activity planning. In sequence, each of the

[1]Considering that the focus in this paper is on the guide, a short version of the rubrics is available at `https://bit.ly/3kLQx0f`.

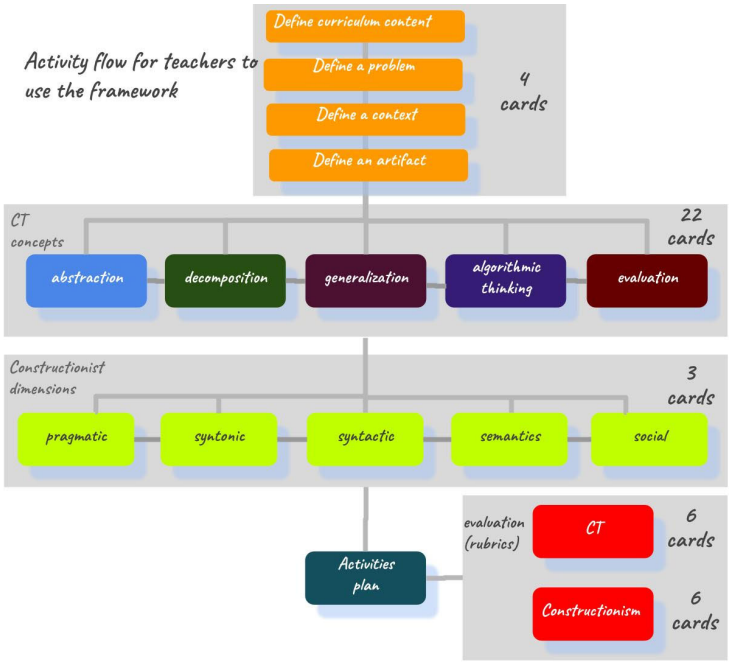

Figure 2. Activity flow for teachers to use the framework. Source: Author

following cards addresses the different levels of approach of the concept, which in this case involves the manipulation or creation of one or more layers of abstraction.

Next, we describe a brief presentation of the different concepts covered in the guide, and identify their integration with the different levels proposed in the CT rubric:

Abstraction: aims to encourage the teacher to develop activities that involve the learner in the **manipulation** of **one** (level 1) or **more** (level 2) layers of representation of a reality. Activity plan can also incorporate strategies so that students are encouraged to **create one** (level 3) or **several** (level 4) layers of abstraction. It can also, according to the planning, involve **establishing the relationships** between different representations that are created by the students (level 5).

Decomposition: the goal is to approach the strategy of comprehending and solving a problem in terms of its component parts. The questions described in the guide aim to induce the teacher to reflect on how to develop or suggest strategies that lead the student to work on this technique, which can be done in different levels of approach: putting the student in **contact with the decomposition/ composition** of problems/ subproblems from **previously established structures** (level 1), involving the student in the process of **solving subproblems** to solve a larger problem (level 3) or integrating the student in the process of **dividing the problem and composing sub-solutions** (level 5).

Generalization: involves planning activities that incorporate the **recognition of patterns** or common characteristics among objects (level 1). It also comprises identifying (part of) a solution of a problem and **generalizing** it so that it can be applied to other similar problems and tasks (level 2) or even planning the involvement of the learners in **creating** models/ standards that can solve a particular category of problems (level 5).

Algorithmic thinking: related to the concept of algorithms, the guide follows the same

logic as the previous ones, first informing about the concept and in sequence, helping to reflect on its use in the activity. It involves planning to work with instructions in a certain order (**sequences**) which store, move and manipulate data/ variables (level 1), but it also encourages the teacher to plan the use of other structures or aspects related to algorithms, such as **decisions and repetitions** (level 2), **modularization** (subroutines - functions/ procedures) (level 3), **parallelism** (level 4), **recursion, and other strategies** (level 5).

Evaluation: consists of developing situations where learners must practice the process of verifying whether a solution, carried out using an algorithm, system or process, is good, adequate to their goal. It may involve carrying out the **evaluation** of a solution **based on previously established processes and criteria** (level 1), asking the students, based on previously defined criteria, to **organize the evaluation process** (level 3) or even plan an activity where the student has to organize an evaluation process **defining the process itself and the criteria to be used** (level 5).

On the integration with the constructionist rubric, the **pragmatic** dimension is related to the manipulation/creation of significant artifacts, leading students to be protagonists in the construction process. The **syntonic** dimension encompasses the participation of students in choosing the themes to be worked on. The **social** dimension encourages sharing, teamwork and community involvement. The **syntactic** dimension is concerned with providing support for the progression of learning. Finally, the **semantic dimension** is related to encouraging multidisciplinary learning and linking with everyday situations.

3. Method for using the practical guide

The use of the practical guide involves the following steps, which must guide teachers in the construction of an activity plan:

Familiarization with the concepts: it is important that the professional must have an overview of the guide components and the concepts that underlie them. This knowledge includes fundamentally the concepts of CT (abstraction, decomposition, generalization, algorithmic thinking, and evaluation) and the constructionist dimensions (pragmatic, syntonic, semantic, syntactic, and social). The evaluation rubrics and the practical guide are the components that will serve as support for the design of the activities, and therefore they must be understood in this stage. A strategy to be adopted for a better understanding of the rubrics consists of their use for the evaluation of previously elaborated activities. The first experience with the guide, on the other hand, should focus on familiarization with its structure, delimited by a set of cards, as well as understanding each of the aspects considered: curriculum content, problematization, context, CT concepts and constructionist dimensions.

Initial design of an activity plan (outline): an outline of an activity plan should be drawn up from the guidelines detailed in the cards. To organize the documentation, two formats can be adopted: through digital documents, where a copy of the cards allows the registration of the fields to be filled; notes on the cards themselves which, when laminated, allow reuse. This step provides a moment of reflection for teachers, being encouraged to integrate the development of the CT skills in the content to be worked on, in the light of the constructionist theory. It should be noted that, at this moment, there is not yet an activity plan in the usual format, but a set of answers to questions from the practical guide that facilitate the future organization of an activity plan.

Table 1. Summary of the process adopted in the proof of concept

Format	Activity (ies) or subject (s) encompassed	Participant (s)
Previous contacts by email	- Sending an invitation letter to the teacher to develop an activity plan based on the practical guide. - Teacher acceptance. - Choice of the theme.	Teacher and researcher
First synchronous meeting	- Presentation of the CT concepts, constructionist dimensions, more effectively by explaining the structure of the rubrics and the practical guide, justifying the interrelationships of the instructional model. - Beginning of the construction process of the activity plan outline based on the questions and guidelines of the practical guide.	Teacher and researcher
Second synchronous meeting	- Finalization of a first version of the plan outline.	Teacher and researcher
Individual work	- Evaluation (application rubrics), identification, and registration of suggestions.	Researcher
Third synchronous meeting	- Presentation of the evaluation with emphasis on the potential for improvement. - Discussion of the results and occasional changes to the outline. - Creation of the activity plan, from the plan outline, using the model. - Final evaluation applying the rubrics. - Occasional changes in the activity plan.	Teacher and researcher

Previous evaluation of answers (from the outline): CT and constructionist rubrics are applied to assess the potential of that initial planning (answers to questions in the practical guide) in the development of CT skills and also, to verify alignment with the constructionist theory.

Reflection and change of some answers (outline modification): based on the evaluation, it is proposed to change the outline to better incorporate the development of CT skills and/ or organize the format of the activities to meet more broadly the indications of the constructionist theory.

Detailing the activity plan: Once the outline has been completed, including changes already made from the results of a previous evaluation, the next step is to formalize it in a document, in tabular format, detailing the activities.

Evaluation and redesign of the activity plan: in this step, the rubrics are applied for evaluation and possible modification and/or complementation of the activity plan.

Other steps: includes the description of the activity in lesson plans, its execution in class and its final assessment, which are not part of the scope of this text.

4. Activity plans generated from the practical guide

In order to analzse the feasibility of using the guide, a proof of concept was carried out, where a Portuguese language teacher developed an activity plan for the 6^0 year of elementary education in Brazil (age 12-13) applying the method described in previous section. Table 1 summarizes the activity plan creation process, which took place in 5 stages, whose format and activities involved in each of them are described in the table.

4.1. Portuguese Language Activity Plan: Graffiti as a starting point for other forms of expression

The plan with the theme graffiti involves reading graffiti images on the walls of the Pelotas city, trying to encompass the perception of students on the images, as well as detailing

the components present in these elements from the creation of artifacts such as text productions, comics and animations, considering curriculum skills in Brazil: EF69LP05, EF69LP07 [MEC 2018]. Next, we have a brief description of the tasks suggested in the design of the activity, as well as some of the relationships with the CT:

Free drawing on brown paper: the student is encouraged to transform graffiti photographs into free drawings. In this case, the reality of the graffiti must be abstracted into another image, using creativity and the expression of feelings. At the end, the teacher should ask students to reflect on original elements that have been included and/ or ignored.

Textual production using one or more images: from a walk-in places with graffiti walls, students will be instructed to carry out a textual production (poem, narrative, review, etc.) from one or more images collected on the walk. In this case, the reality of the graffiti must be abstracted/ refined in a textual form. The theoretical basis (characterization and description of components) of the chosen textual genre must be the guiding element of transposition between the image and the text (thus defining the relationship between the abstraction layers). In addition to abstraction, in the construction of this artifact (production of a text), the student comes into contact with the concept of decomposition. The teacher must encourage the importance of structuring the text in certain components (introduction, development, climax, and conclusion) that can be developed separately to produce the final artifact. To finish the production, the student must be able to organize the components developed in a logical sequence, using the fundamentals of sequential composition (algorithmic thinking).

Textual production evaluation: students will be guided to act in a process of self-evaluation. Based on the teacher's guidance, they will define criteria for evaluating the produced texts and will be encouraged to develop an instrument (form) with the evaluation requirements. This instrument will be applied by each student in their textual production and, later, in some of their colleagues' texts. In the process of constructing the evaluation process, students will be guided to think about the subcomponents. This involves defining requirements, structuring the process, translating to an instrument (form), and other components. Thus, emphasizing the concepts of evaluation and decomposition.

Elaboration and evaluation of a comic book (CB) based on graffiti: following the same steps of textual production, initially students will be introduced to the basic elements that compose a CB (such as, panel, gutter, balloons), in a second step, they must abstract/ refine a graffiti image into a CB and later elaborate, together with the teacher, an evaluation form and apply it to one or more CBs.

Elaboration of an animation on a digital platform: students will be instructed to use the Scratch digital platform [Resnick et al. 2009] to transform their textual production into animations, including scanned images of graffiti. Animation on the digital platform is yet another form of abstraction from reality expressed by graffiti. The students will be guided to create the animation based on some parameters (relationship between the layers) that will be proposed by the teacher. Following the same process as in previous productions, students will be encouraged to think about the components that are necessary for the elaboration of an animation. They will be guided to decompose the creation, separately structuring scenarios, characters, and behaviors. Another concept to be worked on in this activity will be algorithmic thinking. The digital platform will allow the student to

make contact with the development of a program that will naturally involve variables, commands in sequence, decisions, and iterations, among others. Finally, the animation must be evaluated. Based on animations, students must define criteria, prepare a form and carry out the evaluation process.

The creation of artifacts permeates a good part of the planned activities. This aspect is central to the constructionist theory that is based on the construction of knowledge that occurs when the apprentice creates an artifact. Another aspect that is given attention in this plan is socialization. Actions are organized such as reading the textual productions, distributing the comic books, presenting the animation on a digital platform and final discussion with colleagues and teachers about the activities produced. Also the activity plan includes the elaboration of a website where the collected images, the comic books and the links to the animations will be shared. It is also expected that folders with QR-Codes will be posted by the school to publicize the website that presents the students' production. Table 2 presents the concepts of the CT that were highlighted by the teacher, during the three meetings, from the use of the practical guide.

4.2. Activity Plan Evaluation

The outline was previously evaluated, between the second and the third meeting. Figure 3 presents the results of this first evaluation using the **constructionist rubric**. It was found that, at that time, there was no effective planning about the syntactic and social dimensions. Concerning to the social dimension, it was partially contemplated by activities that were planned to be developed in pairs or groups of three students. In order to improve this aspect, a moment of interaction with the community was included in the plan, to present the artifacts and receive feedback. It is important to notice that this moment was not artificially inserted, it was already the teacher's intention to have some form of dissemination of the artifacts produced. The preliminary assessment highlighted this aspect and led the teacher to reflect and incorporate the interaction with the community.

The Syntactic one also received attention, after the preliminary assessment indicated a potential for improvement. It is possible to observe in Figure 3 the score 0 (zero) for this item, as well as the corresponding justification for the given score. In the observations, among other recommendations, it was stated "In the teaching plan there is no indications of materials to be made available to students". In this case, the teacher did not make explicit in the planning the availability of didactic materials that would allow to identify which types of artifacts could be developed, with autonomy, by the students.

The last meeting focused on improving the aspects considered in this preliminary assessment. The changes made have improved the scores. Except the syntactic criterion, all others received a maximum score in the second assessment. Regarding the syntactic criterion, it is not possible to state that the current version of the activity plan contemplates the engagement of different interests and learning styles. Therefore, grade 3 was assigned, indicating that didactic materials tend to enable the inclusion of more complex aspects in the artifact. The evaluation of the plan's potential for the development of CT skills, from the **rubric of the CT**, was also carried out between the second and third meetings and it is described in Figure 4. It is possible to observe that, in the first assessment, 3 was the minimum score achieved in each dimension. This result was considered reasonable and, therefore, the professionals did not proceed with another planning-evaluation cycle.

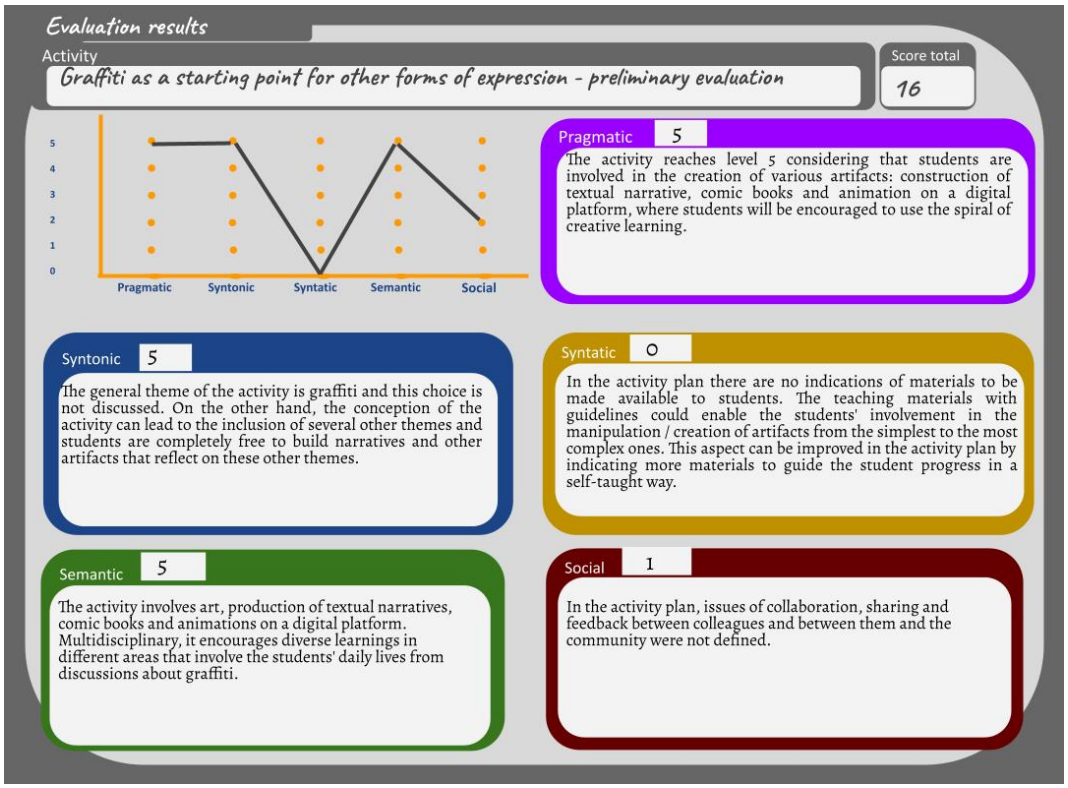

Figure 3. Graffiti as a starting point for other forms of expression - Results of the preliminary constructionist assessment. Source: Author

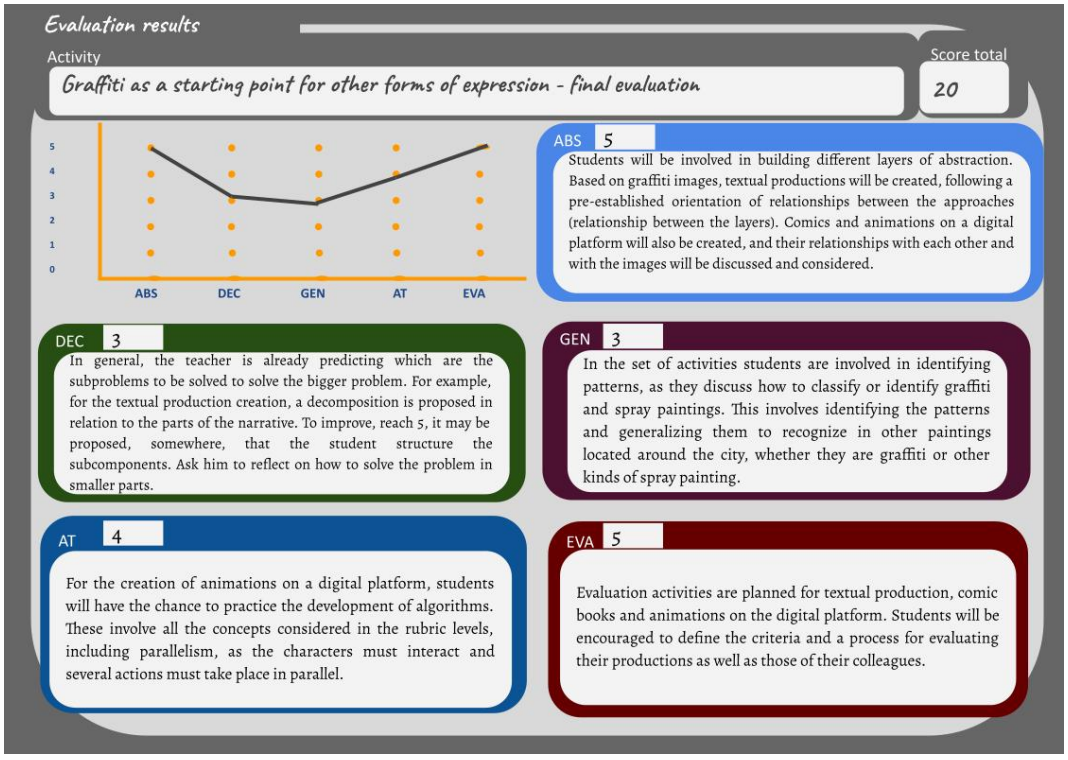

Figure 4. Graffiti as a starting point for other forms of expression - Results of the application of the CT rubric. Source: Author

Table 2. CT concepts present in the activity plan

Concept - Characterization of the concepts identified in the activity plan
Abstraction - A guided city tour, through places with graffiti, will allow the capture of images. Students, when analyzing the images, will be involved with abstractions (images collected by smartphone cameras) from a reality (interventions in the form of graffiti and/ or spray painting). In this case, it is up to the teacher to highlight aspects that the camera captures (or not) and modifies (or not). They will be guided to elaborate their graffiti based on the images and discussions carried out on the walk. This activity allows the student to create an abstraction layer, that is, transform an image, which represents a reality (graffiti) in another image, expressing creativity and feelings about the original one. They will be guided to carry out a textual production (poem, narrative, review, etc.), comic books (scripts and different presentation forms) and animations on a digital platform from one or more images collected on the walk. These activities allow the student to create different layers of abstraction. The students' prior knowledge and the theoretical foundation addressed by the teacher, must be the guiding elements of transposition between the image and the artifact (text, CB, animation), becoming an important element in the relationship between the abstraction layers.
Pattern recognition and generalization - In the classroom, the collected images will be presented and students should participate in a discussion that aims to: identify the differences between graffiti and any other spray painting; recognize the signature of the graffiti artists; identify which messages the graffiti artist wanted to transmit; list the feelings that the images provoke. The analysis of the different images, as representations of reality (abstractions), will allow the exercise of pattern recognition and generalization The goal is to identify which are the patterns in the images that differentiate graffiti from other spray paintings. Based on patterns, we aim to identify the "signatures" or characteristics typical of graffiti artists.
Decomposition - Textual production allows the student to have contact with the concept of decomposition. The need to structure the text in certain components (introduction, development, climax, and conclusion) to produce the final artifact will be reinforced. The same approach will be exercised for creating a CB. The evaluation itself, its construction process, will also be used as an exercise to practice composition/ decomposition. Students will be instructed to divide the evaluation process (or the process of defining the assessment) into subcomponents such as, establishing the criteria, defining the process, proposing an instrument, carrying out the assessment, and presenting the results. In the same way, students will be encouraged to think about the components that are necessary for the elaboration of an animation on a digital platform.
Algorithmic Thinking - To develop a textual production, the student must be able to organize the components in a logical sequence. Similarly, for the elaboration of the CB and according to the proposal of an evaluation process. Each component of them will be planned separately at first, identifying existing relationships, and then they are chained together in a process (step by step). In all these activities, the exercise of the algorithmic thinking takes place in the unplugged format [Thies and Vahrenhold 2012]. On the other hand, in the development of an animation on a digital platform, the learner will be encouraged to use a spiral of creative learning [Resnick 2017] and will have contact with the algorithmic thinking from Scratch.
Evaluation - Students will be guided to create processes for evaluating the textual productions, comics, and animations. Based on the teacher's guidance, they will define criteria to evaluate the artifacts. Students, based on some guidelines from the teacher, will be encouraged to develop an instrument with the assessment requirements. The instruments must be applied to the artifacts and a final discussion will be carried out.

5. Final considerations

This paper presents a proposal for a practical guide that aims to encourage teachers to conceive activities that develop curricular content, incorporate CT skills and consider constructionist dimensions. The proof of concept carried out shows that the guide has the potential to stimulate teachers of k-12 education to propose activities that provides such integration. This can be done without many changes in the activities that would normally be proposed, because it is often a matter of encouraging and guiding the teacher to incorporate CT and constructionist aspects in his plan. Incorporating the development of such skills into school tasks can serve as mental tools for future problem-solving. Other studies will be carried out to identify aspects that can be improved in order to provide greater autonomy for users interested in creating activities based on the guidelines of this instrument as well as, after creating an activity, applying the evaluation rubrics.

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