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Title **Design principles as a theoretical production of Design-Based Research: Contributions of dialectics to a methodology for teaching algorithms and computer programming**

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Abstract A complex educational problem is the starting point for using DBR in education. In this research, the problem involved teaching algorithms in Computer Science based on collaborative learning and the use of a remote laboratory. The teaching and learning of algorithms is a relevant topic for research in education and computing, and we found the right research methodology in DBR. To conduct the research, the question was defined as follows: How can algorithms and programming be taught from the perspective of collaborative learning using a Remote Laboratory in a virtual learning environment? The aim was to develop a methodology for teaching algorithms and programming, with collaborative learning, using a remote laboratory in a virtual learning environment. The DBR was used as a method, based epistemologically on dialectics, producing knowledge, and expanding the characteristics of the method, such as dialog, interaction and collaboration. Two procedures were used to produce the data: a checklist and a focus group. The prototype was evaluated in four itera-

tions: two iterations with teachers and two with students, refining and changing the version. The focus group broadened the dialog about the evaluation. In the results, teachers and students perceived the relevance and consistency of the prototype in a similar way. This agreement points to the soundness of the proposed solution. The results show: the design principle, with a substantive and procedural emphasis; collaborative learning as a methodological solution for teaching algorithms in a remote laboratory, in a dialectical pedagogy.

Keywords *Design-Based Research* in education
Dialectic
Principles of Design
Cooperation
Algorithms & programming

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Design principles as a theoretical production of Design Based Research: Contributions of dialectics to a methodology for teaching algorithms and computer programming

Gidevaldo Novais dos Santos, Emanuel do Rosário Santos Nonato

1.0 Introduction

The Computer Science professional has an important training axis in the study of algorithms to produce digital technologies within their scope of work. The students in this area are exposed to introductory algorithm and programming content from the very first courses.

From the introductory studies of programming, the student should understand that the objective at that time is to understand that the programmer is a solver of computable problems – that is, the programmer is someone who creates a computational solution to a given problem that has been presented to them.

Creating *software* involves identifying a problem that can be solved using a digital device, planning the solution, and implementing this solution by coding it in a programming language. Planning and implementing this solution involve creating an algorithm that meets the characteristics identified as suitable for the solution created.

The process described above is part of the knowledge that computer science students meet from the very beginning of a degree course in the field. Some students, at this introductory stage of programming knowledge, knowing algorithms and a programming language, realize that understanding and putting into practice knowledge about algorithms and programming is not elementary.

The difficulty of learning algorithms and programming is a constant in the reports of researchers, as stated by Robins, Rountree & Rountree (2003, p. 137), "learning to program is hard. Novice programmers suffer from a wide range of difficulties and deficits. Programming courses are generally regarded as difficult, and often have the highest dropout rates", and considering the difficulties that some students have in learning the introductory content of algorithms and programming, we seek, through the creation of artifacts and learning contexts, to promote improvements in the teaching and learning processes of the content that is part of this training.

This is how the Remote Laboratory in a Virtual Learning Environment, RLVLE -therefore LARA, was created, as a pedagogical architecture

that should integrate technological resources and teaching and learning methodology in computer education, from a collaborative perspective (Lopes, Gomes, Trindade, Silva & Lima, 2017). In the presentation by its creators, LARA is understood as a UESB project to develop a pedagogical architecture that integrates technological resources and teaching methods to improve the learning processes in robotics, computer programming, algorithms, intelligent systems, among others. One of the goals of this project has been the construction of a new remote robotics laboratory and the development of an online programming environment that enables students to carry out experiments in distance (education) (Lopes et al., 2017, p. 527). Although it is a resource applicable to distance education, as it uses online tools and environments, the initial use proposed is to support face-to-face teaching. Collaboration can take place in both modes of use. Thus, the teacher can conduct the teaching process collaboratively before, during and after using LARA and the students can act collaboratively in the learning processes before, during and after using LARA. In this context, we consider that the research problem we are trying to solve is how to teach algorithms and programming in a remote laboratory, from a collaborative learning perspective. For this question, we understand that the answer is to create a methodology for teaching algorithms. In this real-world context, we do not have a controlled environment, in other words, the problem identified is a complex one. The solution must involve a more elaborate investigative process, and we also consider what Barab (2014, p. 151) tells us, stating that "the messiness of real-world practice must be recognized, understood, and integrated as part of theoretical claims if the claims are to have real-world explanatory value", and this value could be presented by the community involved in solving the problem, i.e. teachers and students, which led us to the decision to use *design-based research* (DBR) in education as the appropriate research method. According to Kelly (2010, p. 75), DBR is recommended when "the problem facing learning or teaching is substantial and daunting how-to-do guidelines available for addressing the problem are unavailable". In our context, we have a remote laboratory (Fig. 1) with a programming environment, called a Control and Programming Environment (CPE), "an online programming platform that provides basic functions to create and test experiments with a mobile robot", and it "can be controlled by using C/C++ programming language" (Lopes et al., 2017, p. 526). It does not have a teaching methodology for using its available resources, but it can have different approaches. It is an open problem, as suggested by Kelly (2010), when he says that "in other words, design research is most appropriate for *open*, or more appropriately, wicked problems" (Kelly, 2010, p. 75).

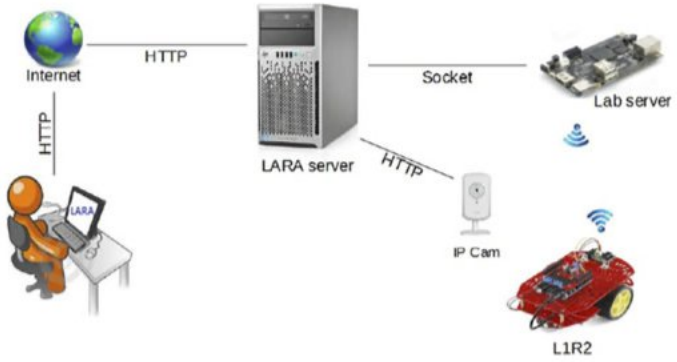

Figure. 1. LARA's Control and Programming Environment

Source: Lopes et al. (2017, p. 527)

In this sense, we understand that the creation of a teaching methodology for algorithms and programming in a remote laboratory from a collaborative perspective has the characteristics of an open problem. The DBR methodology is recommended for investigating and producing results. The teaching methodology is a proposal for LARA, but it can be used in other contexts, if the specificities are adapted.

When we identify the research problem, we also identify the theoretical categories that are used to underpin the discussions that guide the studies and the creation of the practical solution, i.e., a first product that DBR produces. It is also important to mention that having an epistemological basis for conducting the investigation processes in the research is fundamental to understanding the existing relationships of the results achieved and arriving more easily at the local theories and design principles, as a theoretical result, which is the second product of the DBR. What we have here, then, is a discussion of the theoretical results, also known as design principle and local theories, achieved through some iterations of research cycles in the DBR and based on the epistemological choice that provides the basis to produce knowledge in this scientific investigation. Dialectics was then the epistemological choice for DBR, due to the conceptual affinity of its constituent elements with the methods of data production and collection and the interest in the production of knowledge in research, both in the practical aspect – the methodology of teaching algorithms and programming – and in the theoretical aspect, represented by the principles of design and local theories. This discussion is based on classic authors from the philosophy of science, language, psychology and, of course, DBR research methodology in education.

2.0 Methodological principles

This section presents the elements that make up the research methodology of this investigation: the research method, the epistemological foundations chosen, the methods of data production and collection and the conceptual discussion of the characteristics of the DBR with dialectics, in a comparative way between these two elements.

2.1 Context of the case study

When defining the research problem for which we would seek a solution, we understood that it had the characteristics for which the DBR promotes, through its process, a contextualized solution (Plomp, Nieveen, Nonato & Matta, 2018). The phases were then planned, which according to Plomp et al. (2018) comprise three stages: 1) preliminary research, a stage in which the theoretical and conceptual framework is built; 2) the development or prototyping phase, in which the prototype is created and formative evaluation is carried out in iterative cycles, until the product is fully detailed; 3) the evaluation phase, whose summative evaluation will indicate the effectiveness of the educational product created (Plomp, 2018 and Nieveen & Folmer, 2018). DBR produces and collects data from the formative evaluation of the proposed artifact, initially in the form of a prototype which, through successive refinements in research micro-cycles, evolves into the finished product. So, for our research, we chose screening the focus group and the methods for data collection as well. Consequently, we made formative evaluation, with the prototype at the *design proposal* stage, using the criteria of *relevance* and *consistency* (Nieveen & Folmer, 2018) for this evaluation. To make up the research group[1], teachers who teach or have taught introductory programming courses in Computing (Computer Science or Information Systems) and students taking Algorithms and Programming I (introductory programming course) were invited. Thirteen teachers and thirteen students responded to the invitation. They evaluated the prototype at the "design proposal" stage, using the criteria of relevance and consistency, at different times, when each group dialogued only with their peers. Table 1 shows the distribution of research participants by activity, the method of production and data collection and what was done in each of the activities.

Table 1
Collaborators, data generation methods and activities.

Iteration (It)	Employees	Quantity	Method	Activity
1	Teachers/ students	6 / 9	Focus group	Prototype creation – version 1
2	Teachers	13	Sorting	Evaluation of version 1
3	Teachers	13	Sorting	Version 2 evaluation
4	Teachers	4	Focus group	Discussion of It3 results

[1] The research group is made up of all the collaborators in the ongoing research. Collaborators, in this case, represent those interested in the product that will be developed and who are part of the context of the problem studied and for whom the solution is of interest.

5	Students	13	Screening/ focus group	Evaluation of version 1
6	Students	13	Sorting	Version 2 evaluation
7	Lecturer	01	Online form	Delving deeper into the collaborative teaching experience

Source: authorship, 2023.

Table 1 shows the iterative process, in which it was possible to draw the first lines of the prototype's creation, with the initial ideas of the research collaborators – teachers and students – as an outline of the characteristics that should make up the methodology. The following iterations were used for the formative evaluation of the versions and other activities that were identified as necessary, such as the focus group with the results of the third iteration and an in-depth look at the experience of a collaborative activity carried out by one of the collaborating teachers.

The choice of data collection method and the conduct of the process have direct implications for dialectics as an epistemology in this research and considerations about these connections will be discussed in the following sections.

2.2 The epistemological foundations

This research took as its object the teaching of algorithms and programming in a remote laboratory and we added an element that would give it some uniqueness, such as collaborative learning.

The choice of collaborative learning as the foundation of the teaching methodology to be created led us to Vygotsky's (2007) socio-interactionism as an epistemological basis, which presents a dialectical conception for development and learning, that is, learning is presented from two levels of development, such as the actual level of development, which the individual knows how to do alone, and the potential, which the individual can learn. The work to promote learning must be carried out in the difference between these two levels, called the zone of proximal development, in which the learner can do with the help of someone more experienced, in other words, through collaboration (Vygotsky, 2007)

Vygotsky's (2007) dialectical conception of learning has language as a mediator of educational processes, teaching and learning. Therefore, the concept of dialogic relations (Bakhtin, 1995) helps us to understand that the interaction between the participants who collaborate in the investigation and creation of the intended teaching methodology takes place through dialog. In this sense, we also used the concept of polyphony (Bakhtin, 1995), considering that the voices of the participants, when they make their evaluations and present their considerations, have the same value and are part of a continuous process of improving the product created.

In this way, dialectics is present in all investigative processes, producing a basis for the creation of knowledge in research, contributing to the perception of a concrete reality within the context studied and guiding the identification of elements for analysis.

In the perception of reality, critical thinking helps us to understand the interest of the research in progress. In this context, we turn to Habermas (2014) to justify that our interest, when we use an epistemological basis guided by criticism, is the emancipation of the subjects. In this case, as we are dealing with the creation of a teaching methodology aimed at students at university, we are committed to an education that has this purpose.

Thus, we are guided by a critical-dialectical conception to produce knowledge in this research, as well as for conceiving the product of a practical nature, that is, the product that constitutes one of the results of this investigation.

2.3 Data production and collection methods: dialectical connections

Evaluations in DBR, both formative and summative, are fundamental to the research and production of the artifacts that the methodology is used to create. The choice of instruments to be used in the evaluation process must be consistent with the ultimate interests in the production of knowledge that will take place during the research.
In this research, we chose screening and focus groups as evaluation methods, in line with what Nieveen and Folmer (2018) recommend, and these choices, which made up the research design, proved to be consistent with the entire methodological design. Table 2 shows the methods used and the characteristics that justify the coherence with the entire research plan.

Table 2
Evaluation, production and data collection methods

Method	How it was used	Characteristics / Application of the epistemological basis
Sorting	- An online form presented the characteristics of the prototype, and each characteristic was associated with an option for evaluation: *Relevant*, *Slightly relevant* and *Not relevant*; - the online meeting was recorded in video and audio (*Google Meet*, with the teachers) or audio only (*Discord*[2], with the	- This evaluation followed an objective form on a scale with three options in which the teacher or student had to make a choice; - despite an objective choice on the scale, the evaluator could talk about each characteristic: ask questions, express an opinion, talk about some classroom experience - if they've done the same or

[2] App used for online meetings of groups with common interests. Available at

	students), so that the dialog between the collaborators and between the collaborators and the researcher could also be used as data; - in the second iteration using the form for evaluating the new version of the prototype, still at the design proposal stage, a field was created for comments on each feature.	something similar, suggest and present the results obtained from their practice; - the "comment" field, inserted in the online form, unlike the evaluation of the characteristics, was not obligatory to fill in, but was placed as an option to justify the choice of relevance; - although the objective evaluation of relevance was the most important aspect of this stage, the secondary production of data through dialogs proved to be important for the analysis, within the epistemological basis.
Focus group	- Group meeting of teachers/students in an online environment (*Google Meet/Discord*), with audio recording of the dialog; - the meeting was led by questions addressed to all those present and the dialog took place between collaborators and between them and the researcher; - teachers who had answered on the form (first or second version) that some of the characteristics presented for the prototype were "not relevant" were invited to the focus group – we were trying to understand why each one considered this response to the characteristics; - the students evaluated the first version of the prototype in an online form in a *Discord* call, so that the dialog between the collaborators and between them and the researcher produced data for analysis	- At this point, the focus was on the dialog between everyone present, as the main source of data production; - the characteristics that had at least one choice of "not relevant" were presented, but it was not indicated which teacher made the choice, so the discussion with the justifications, argumentation and synthesis took place among all those present; - as the characteristics designed for the teaching methodology were obtained from other research in the area, understanding the choice was fundamental for analyzing the results obtained; - the evaluation carried out by the students would serve to contrast the two sides of the processes of teaching and learning algorithms and programming, so from the evaluation of the first version, dialog was present to produce and collect important data for the analysis.

https://discord.com

	in a focus group format.	

Source: authorship, 2023

In the evaluation using the screening, with the possibility of dialog between the participants, it was possible to produce fundamental data for the analysis in the next stage. Although the focus was on the objective evaluation of the relevance criterion, consistency was evaluated concomitantly in the debate between the participants.
The form of data production and collection chosen proved to be essential, as we found in this process the application of dialogic relationships (Bakhtin, 1997), and in these relationships it was possible to understand the meanings of the observations made by the evaluators, and to follow the expected movement of the debate on the experiences and knowledge that each participant could present to us.
Fig. 2 shows all the iterations carried out during the cycle that was completed for this stage of the research and the prototype took on two different versions based on the participants' evaluation. Although they are two different versions, both are at the same stage, called the "design proposal", in which the characteristics taken from the theoretical-conceptual framework produced in the preliminary phase (first phase) were presented.

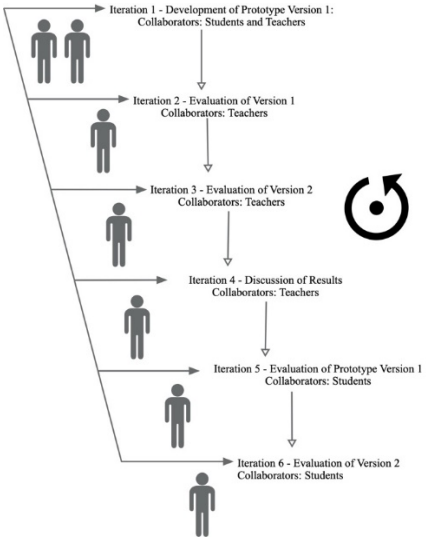

Figure 2. Development Phase or Prototypical Phase of the research
Source: authorship, 2023

The *It1*[3], *It2* and *It5* iterations, described in Table 2 and illustrated in Fig. 2, were unique moments in the research process. It led to interesting dialogs with exchanges of experiences and narratives by the teachers of their successful practices in the classroom, as well as those that were unsuccessful. We can consider this moment to be an excellent research experience, since, due to the way the data production method was applied (it was carried out *online* due to the[4] pandemic

[3] In this iteration, unlike others, teachers and students participated at the same time, which is why we illustrated it with two puppets to indicate that the evaluation was carried out by two different actors.

[4] The COVID-19 (Corona Virus Disease) pandemic, characterized mainly by a severe acute respiratory syndrome, was declared by the WHO to begin in March 2020 and

underway at the time), it was possible to produce and collect data beyond what was expected, or even beyond what was planned to be produced or collected.
The experiment was successful in its purpose and in the results obtained due to the possibility of dialog between all the participants in the research. All the collaborators could talk to each other while the prototype was being evaluated, presenting results from their experiences as teachers of introductory programming courses, or curriculum planning for computer science courses, while commenting on the characteristics of the teaching methodology present in the prototype. At this point, it was possible to learn about evaluative elements beyond what was provided for in the form, and this was only possible, we stress, because of the dialog.

2.4 The prototype: design specifications

The prototype of the teaching methodology was produced based on a review of the literature and studies on the problem published by the academic community that researches the subject of computer education and based on the theoretical foundations that are used to produce this knowledge.
It was important that the results of the preliminary phase were adapted to our context since the solution presented will meet LARA's need to have its own methodology for teaching algorithms and programming.
Considering the literature review, it was possible to define three categories for the prototype to be developed: didactic planning, collaboration and curriculum. The characteristics of the prototype that would be evaluated by the research collaborators would be grouped according to these categories.
The characteristics of the prototype were then defined, in the stage called design specifications, which is conceptualized as "a first and general description of the intervention in which attention is paid to its substantive parts. This sketch has been based on preliminary research activities" (Nieveen, 2010, p. 89). This version of the prototype can be seen in Appendix A, with a description of each feature.
In the preliminary phase, in which the conceptual structure was developed, the concepts involved in proposing the characteristics were based on studies produced over a wide period. We used the concepts of scaffolding (Wood, Bruner & Ross, 1976), the concept of subsumption as an Ausubel's (2000) concept and Kessler & Anderson (1986), Wiedenbeck (1989), Lopes et al. (2017) as practices for applying the concept of subsumption, collaboration (Murphy, 2004), (Vygotsky, 2007); Zone of Proximal Development and mediation (Vygotsky, 2007).
Table 3 shows the *didactic planning* category and the distribution of characteristics by category. In this category are the characteristics that present preparatory activities for classes, as well as their execution: lesson plans, assessment and feedback.
This category includes actions that must be carried out by the teacher in any course. However, the actions are proposed based on a theor-

end in May 2023.

etical foundation: collaboratively planned actions tend to create support for students and promote engagement and a process of self-regulation, such as scaffolding (Wood, Bruner & Ross, 1976) and subsumption (Ausubel, 2000).

Table 3
Characteristics of the algorithms and programming teaching methodology prototype from the Didactic Planning category

Category	Characteristic	
Didactic Planning	C1	Start with a diagnostic assessment to identify what the students already know about the themes of the course.
	C9	Make lesson plans available, with clear and well-defined objectives at each teaching stage.
	C10	Make the course lesson objectives known to all students.
	C13	Use formative assessment at each stage (identify gaps in the content worked on).
	C14	Use self-assessment (based on a script, indicating the criteria).
	C16	Produce feedback from the assessment.

Table 4 shows the collaboration category and its corresponding characteristics. In this category we have the set of characteristics that involve interaction between students to carry out the tasks in the curriculum component and the interaction between students and the teacher.

Table 4
Characteristics of the prototype methodology for teaching algorithms and programming in the Collaboration category

Category	Characteristic	
Collaboration	C6	Carry out activities in groups and the group must produce an artifact collaboratively.
	C7	Allow dialog between group members and between the group and the teacher during class activities.
	C8	Allow any doubts that the group cannot resolve among its members to be taken to the teacher.

Collaboration as a founding concept of the methodology is present in the work of Vygotsky (2007) who presents the concept of the zone of proximal development and the role of peers in the learning process in this zone, in a contribution from the group among its participants. To help work on the idea of collaboration in an online environment, we

used Murphy (2004) and his model. It helped us with the characteristics that promote interaction and dialog, both in a virtual environment and in person. The contributions of Murphy (2004) and Vygotsky (2007) can also be seen in the other categories. Table 5 shows the characteristics that make up the curriculum category. This category includes the set of features that present activities aimed at developing the content and skills laid down in the curriculum. This category directly involves the content approach. In this sense, the characteristics that deal with problem-solving, the formalization of the concept and the definition of algorithms, algorithmic structures and the use of metaphors for the conceptual apprehension of this content were included. The discussions of Wood; Bruner & Ross (1976), Ausubel (2000), Kessler & Anderson (1986), Wiedenbeck (1989), Lopes et al. (2017) and (Vygotsky, 2007) supported this elaboration.

Table 5
Characteristics of the prototype methodology for teaching algorithms and programming in the Curriculum category

Category	Characteristic	
Curriculum	C2	Present examples of algorithms, abstracting the formal definition, to understand elements such as: input, output, decision, repetition, before the conceptual formalization (definition).
	C3	Present examples of algorithms from the most general to the most specific (from the mathematical definition to the computational context).
	C4	Present the structures: sequential, conditional, repetition; then present: arrays, subroutines (functions and procedures), recursion.
	C11	Create problems that lead to the reasoning required to learn programming logic.
	C12	When presenting problems to be solved using algorithms, suggest the solution steps as a method.
	C18	Use algorithm design [plan, develop and test].

Although a division into categories was used to map specific actions at this stage of the prototype (design specifications), the concepts on which the characteristics are based run through all of them. Thus, we will find the concept of collaboration not only in the category that bears this name, but also in the others, as well as actions that refer to curriculum issues.

2.5 The complementary relationship between the DBR as a method and dialectical epistemology

McKenney and Reeves (2012) list some of the elements of DBR as important characteristics that should be considered when thinking about its application. According to these authors, DBR is:

1) **theoretically oriented**, that is, the method initially requires a consistent theoretical study to guide the design, intervention and evaluation of the proposal, from the initial steps in the form of a prototype and in each context. This theoretical orientation is fundamental to the development of the entire research;

2) **interventionist,** since it acts in a specific context, promotes the resolution of a real problem, drawing up a proposal with a focus on practical aspects of the application;

3) **collaborative**, because it seeks results from a team made up of people interested in solving the problem identified, who know the context and have experience in the activities that are part of that environment, creating partnerships and agreements that contribute to the production of data and the investigation as a whole;

4) **fundamentally responsive**, it manages to produce adequate answers to the problem identified, by bringing together the knowledge brought by the theories that underpin the research, the knowledge of a practical nature that the research participants and collaborators present in their dialog with the researchers and the evaluation within a specific context;

5) **Iterative**, which is one of the hallmarks of the design-based research process and the creation of a product – which can be called a solution – from a prototype and with the collaboration of several people. The iterations are made up of complete research micro-cycles, with the development of a prototype version of the solution, followed by evaluation, analysis of the data produced, and refinement based on the evaluation, producing a new version and all the following steps. In this case, even if the researchers decide on a version that is considered finalized for use, this version can still be refined, producing improvements with the evaluation of those who use the solution in practice, in a continuous movement of changes and updates.

In addition to the characteristics already announced and presented, Plomp (2018) reinforces that the DBR has a natural link to the **context** of execution, addressing the variables or categories in a systemic way and not in isolation. The context is responsible for characterizing the scope of generalization of the solution found and is the environment for which the *design* principles and local theories will be enunciated.

The characteristics that have been described, based on what McKenney and Reeves (2012) and Plomp (2018) present to us, constitute an important way of understanding DBR as a research method in an educational context and point to concepts that can be used to choose the epistemological foundation that guides the production of knowledge in research.

In this way, we consider dialectics to be an appropriate epistemological choice, in line with the characteristics of DBR, since its categories are

clearly defined and present elements comparable to DBR. Although we have not used dialectics as a method in this research, it is worth pointing out that these categories emerge naturally when we use its foundations as our epistemological support. Thus, the categories of *totality*, *mediation* and *contradiction* are present throughout the process, ensuring coherence in the knowledge production activities conducted in the research. These categories may be indicative of how the DBR is characterized, within applied research, as a method that has dialectical elements within it.

We began this discussion with the category of *totality*, and recall that the DBR, whose research process begins with the creation of a theoretical framework to guide all the planned production (*theoretically oriented*), seeks to understand the existing relationships of the object of research in reality, understanding this "reality as a concrete totality, that is, as a structured whole in the course of development and self-creation" (Kosik, 1976, p. 43), including in this idea the characteristic of *iterativity*, which reflects the research itself as a continuous movement, from the point of view of its production and the results to be achieved. In this sense, therefore, we have taken the *theoretically oriented* and *iterative* characteristics of the DBR and associated them with the category of *totality*, as we understand that the production of knowledge occurs in the understanding of the relations and determinations of the object under study, which consequently leads us to the other categories, such as *mediation*, which is naturally involved in the perception of the relations and determinations of the object being researched, and *contradiction*. According to Lefebvre (1995, p. 237), "between the universal and the concrete, it is impossible to suppress the mediation of the particular", which leads us to the fact that, in the definitions of the investigative steps guided by the DBR, the creation of the intervention (the DBR is *interventionist*) is a mediated realization, further reinforcing that this happens in a contextualized way. Vygotsky's (2004, p. 368) statement corroborates this idea, arguing that "we can say that each person is to a greater or lesser degree the model of society, or rather of the class to which he belongs, since the totality of social relations is reflected in him".

Dialectical *contradiction*, in turn, which in Lefebvre's (1995, p. 238) argument is understood as "a (full, concrete) inclusion of the contradictory in each other and, at the same time, an active exclusion. (...). The dialectical method seeks to capture the link, the unity, the movement that engenders the contradictory, that opposes them, that causes them to clash, that breaks them down or overcomes them". It can be seen in the characteristics of collaboration and responsiveness, which in a very similar way, provide a collective construction, overcoming differences of ideas present in the collective, and appropriate to the problem for which they seek a solution. The existence of a theoretical framework guiding the solution becomes fundamental in overcoming the contradictions that naturally emerge from productions involving solutions to complex and concrete problems. In short, what this comparison reveals is that, conceptually, DBR and the categories of dialectics share common points, such as the consideration of multiple aspects, relationships and determinations of a given research object; the importance of interactions, and the capacity for overcoming, responsible for changes over time. All of this is based on dialog, collaboration and interaction.

3.0 Results: discussing the knowledge built up

The DBR produces its results through iterative cycles, in which evaluation is the form used to produce and collect data, using some specific instruments. In this context, the formative evaluation processes, emphasizing the facilitation of interaction and the constant presence of dialog, made it possible to obtain preliminary results of significant relevance in a single cycle. By using dialectics as the foundation of knowledge production, it was essential that participants were able to interact through dialog, sharing their experiences, listening to other ideas and arguing about their ideas and the methodology proposal that was being evaluated; in the dynamics of the evaluation process, it was possible to go beyond the objective evaluation initially proposed (screening using a checklist) and collect fundamental data for analysis. The prototype evaluated underwent refinements that resulted in two different versions, but both still in the design proposal stage (Nieveen & Folmer, 2018); in this case, the prototype presented characteristics that were extracted from the theoretical framework produced in the preliminary phase (first phase). The characteristics of the prototype were grouped into three categories: **1) didactic planning** – a category that groups together the teaching activities that precede their actions in the classroom and, in the case of this methodology, has elements of collaboration between teachers and students; **2) collaboration** – groups together the characteristics that are responsible for defining the conduct of learning processes as a cohesive group that can produce an artifact jointly; **3) curriculum** – made up of the characteristics that refer to the training of computer science students, such as the content, skills and competencies expected of graduates of the Computer Science course. Thus, of the characteristics presented in the prototype, at the "design proposal" stage, in order to assess their relevance and consistency, it was possible to identify a convergence of ideas in the two groups of evaluators – teachers and students – showing, initially, that the differences are minimal in the way of thinking about the teaching of algorithms and programming between these two groups, showing more agreement than its opposite and that the solidity of the solution to the problem is something feasible, as can be seen in Fig. 3.

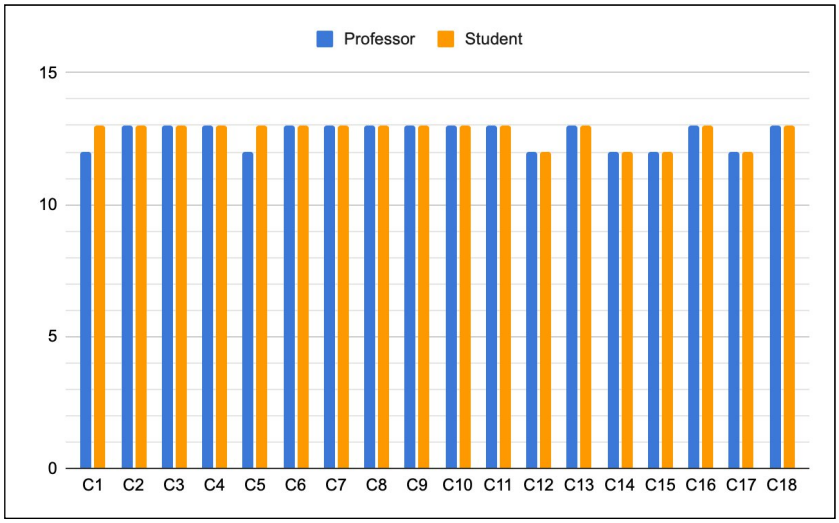

Figure 3. Comparison of the relevance of the characteristics in the evaluation of teachers and students.
Source: survey data, 2023

Fig. 3 shows a comparison between the results of the two groups of evaluators' assessment of the prototype's features, indicated in the graph as C1 to C18. Three possible answers were used to evaluate the characteristics of the teaching methodology: relevant, not very relevant and not relevant. For the graph in Fig. 3, the "not relevant" votes given by the students and teachers were removed, so that only what was considered relevant at some level remained.

As partial results of this stage of the research, it is possible to highlight, firstly, that in the assessment of teachers and students, the characteristics proposed for the methodology of teaching algorithms and programming have *content and construct validity*, i.e. the characteristics are relevant and consistent. Secondly, we highlight the result that collaboration, which was initially designed to underpin the learning process, can contribute to teaching processes, since students have the potential to contribute to the didactic planning of the subject's activities. From the results obtained in this cycle, it was possible to identify a *design* principle with a substantive and procedural emphasis; we considered the main design principle obtained in this cycle of research, which we enunciate as follows: *If you want to design a teaching methodology for algorithms and programming, in an undergraduate course in Computer Science, using a remote laboratory in AVA from a collaborative learning perspective, your best option is to give the methodology a collaborative character, and to do this through a dialectical pedagogical practice, because of the contradictory elements immanent to human practices, due to the different experiences of each one, but whose expected results for the activity in question can move towards the convergence of ideas, based on dialog*.

The principle set out above is based on the concepts of collaboration in Murphy (2004) and Vygotsky (2007) and dialog in Bakhtin (1997), in perfect harmony with dialectics in Lefebvre (1995), the epistemology chosen to underpin our research, and which was verified in practice by comparing the results of the teachers' and students' evaluation of the prototype's characteristics.

As local theories, obtained because of this research, we can also enunciate some complementary design principles based on the categories that organize the teaching methodology and which have a substantive emphasis as their main attribute, since they explain essential characteristics of what we want for the intervention that is under development:

- **Complementary principle 1**: Collaboration must be understood conceptually and practically by all those involved in the teaching and learning processes. This understanding is fundamental for creating coherence in the actions involved in the processes, from the initial planning to the final evaluation. Key words for this principle include: social interaction, dialog, otherness, cooperation, sharing, engagement, collaborative systems and multimodality.
- **Complementary principle 2**: The didactic planning of activities for the teaching of algorithms and programming must provide for the construction of tacit knowledge, based on the socio-

emotional support placed at the service of the subject's activities. This principle refers to the construction of knowledge, led by the teacher, which provides the student with the conditions to develop self-regulation and is capable, for example, of leading them to carry out a self-assessment. Key words for this principle are: scaffolding, dialog, engagement, self-regulation, practice, self-assessment, tacit knowledge.

- **Complementary principle 3**: The planning of teaching and learning strategies should include activities that promote the development of knowledge that does not depend on specific subject content, but which belongs to the course curriculum and is related to the content it covers. In this principle, we are looking for support for student autonomy, tacit knowledge and an independent way of accessing the content that the course promotes. The key words for this principle are: good practice, group work, cooperation, leadership. These results are revealing the epistemological foundation used, since it presents elements that characterize student emancipation. They reveal that the investigative process was conducted coherently, that as well as guiding the activities of the research process, it also guided the development of the intended educational product – the methodology for teaching algorithms and programming in a remote laboratory from a collaborative perspective – and that the development, supported by dialectics as an epistemology, led to the principles that are intended to guide the practice of teachers, with the involvement of students in the process, producing meaning in the planning for teaching and learning.

As design principles with a substantive emphasis, the three principles listed reveal attributes of the categories we used to compose the prototype developed, such as *collaboration*, *didactic planning* and *curriculum*. Although we did not distinguish the principles by category, it is possible to infer this organization; we did not do so because we were aware of the juxtaposition between them.

It is possible to understand the extent of what was produced in this research by analyzing that some results led to the identification of the collaboration category as a robust concept, which aggregates so many other concepts that result in practical actions for teachers and students.

We dealt with collaboration from Murphy's *framework* (2004) and, with this starting point, it was also necessary to discuss:

- social interaction as a ritual, with fundamental elements for this interaction to be the result of the perception of the other, as a human individual, along the lines presented by Goffman (2011) and Goffman (2014);
- *dialog* as a process of articulating the individual's worldview in relation to the group, their experiences and knowledge, and therefore their contributions to the activity under development. Through dialog, everyone's contributions are accommodated, based on mediation towards the common goal of that moment. An understanding of *alterity* is indispensable in a dialogical process that has many voices to be heard, as we can read in Freire (2018) and Bakhtin (1997);
- *cooperation* and *sharing* as elements of the collaborative process, since each component of the group contributes, or should contribute, to the elaboration of the artifact that solves the proposed problem. Cooperating in the work and sharing common objectives

lead to the group building a sense of common purpose (Murphy, 2004). The results of these reflections have consequences for people – teachers and students –, for didactic-pedagogical activities – planning and execution of teaching and learning strategies –and for technological mediation on how to use the remote laboratory as a space for experimentation and promotion of collaborative learning.

4.0 Conclusion

Having reached this stage of the research, it is possible to reaffirm that the problem of this research, i.e. how to teach algorithms and programming in a remote laboratory from a collaborative learning perspective, is suitable for using DBR in education as a method. Knowing the concepts that characterize DBR as a design-based methodology and that its structure includes context, collaboration and iterativity as its constituent elements, we can use them as clues for other complementary methodological choices. The choice of dialectical epistemology characterizes, according to the theoretical bases used to support our research, our interest in the results of this research and even a conception of education that we desire, that is, human emancipation mediated by the educational processes of teaching and learning. The design principles found were consistent with the theoretical choices that underpinned the research.

The creation of a teaching methodology for algorithms and programming was the opportunity found to think about educational processes that were mediated by dialog, recognition of the other and differences, individual contributions in a collective construction. In this sense, dialectics was fundamental as an epistemological basis; it was possible to carry out research with collaborative characteristics to create a teaching methodology from a collaborative learning perspective. We then distinguished design principles that emerged at the end of the process and that reinforce how collaboration is a robust concept, which brings together so many other concepts conveyed by the movement of dialectics, in action, through its categories; hence we discuss interaction, dialog, mediation, contradiction, otherness and totality, because we understand that educational processes are creators of new realities, based on a critical understanding of the reality experienced, its relationships and its determinations. Regarding the continuity of the research, it is important to highlight that work is in progress to complete the other prototype development cycles and the application of the methodology for teaching algorithms and programming in a regular course for the summative evaluation of the developed product. As part of this research, a guide will be developed for using the teaching methodology in similar contexts.

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