Promoting Mediation in Learning Error on Teaching Algorithms

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Abstract: This paper addresses the results of a research on the adoption of a computer platform for mediation of learning errors in algorithm exercises for computer science students. The importance of the interaction between teacher and learner is discussed as a way to reconsider learning errors. The need to evaluate tools for mediation of learning errors is brought to the discussion. The essential activities a teacher should develop using a tool that helps in the practice of algorithm teaching are listed, and based on them, a method that promotes the interaction between teacher and learners is proposed as a mean to enhance the effectiveness in mediation of learning errors.

1 INTRODUCTION

One of strategies for effective acquisition of knowledge or skills is learning error mediation process, which essencially consists of a presentation of a help message for the learner, when a mistake is made (Ramos, 2011). The use of tools to support the mediation of errors can help the learning-teaching process (Moura and Peres, 2017). The FARMA-ALG (Kutzke and Direne, 2014) is a tool based on error mediation that, through analysis of relations and interconnections of learner errors, can capture the relevant properties of this type of mediation.

With the availability of tools that allows mediation of learning error on algorithm contents, it is identified the necessity to study its use by teachers and learners. Besides that, there is a lack of methods which guide the creation of new ways of instructional project on a social interactionist model, based on the interaction by technology. The results of the efforts of teacher may fall short expectations if there is not a guide which orients him/her on the correct and effective use of computational tools focusing on interactionism.

This paper presents the results of a research applying the FARMA-ALG tool for the observation of learner-teacher interaction with error mediation on first algorithms course of computer science undergraduate students. It was observed a reduction of 46% on the amount of erroneous attempts after learners had received some sort of intervention from the teacher. There was an increase of 7.5% on the amount of correct answers to the exercises. Despite these positive results, it was verified that the percentage of incorrect answers, was still high, close to 70% of all answers, even with interventions of the teacher. It was also observed that the level of interaction was extremely low, reaching only 1.93% of the total. Considering the amount of submitted answers by the learners that received some sort of interaction was quite restrict, it was noticed that such behaviour occurs, largely, due to the lack of a method that gives orientations for the teacher to correctly use the interaction resources that FARMA-ALG provides.

Considering the above mentioned, this paper has the objective of presenting the inherent aspects in learning error mediation on teaching algorithms, bringing to the discussion the need of evaluating a tool that work on the context of learning error mediation, and proposing a method which promotes interaction at error mediation process.

This paper is organized as follows. Section 2 presents the conceptual basis of mediation of learning errors. Section 3 depicts an evaluation of learner-teacher interaction. A method to guide the teaching process to promote the interaction is proposed in Section 4. Finally, Section 5 concludes with considerations and future work.

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2 LEARNING ERRORS MEDIATION

Computer programming is a complex and high level activity that demand a high cognitive load. This complex scenario requires hard work from both teachers and learners on the process of teaching and learning. During this process, the learner faces difficulties that, potentially, generate errors (incorrect answers to exercises).

During the teaching of complex knowledge areas, such as computer programming, it is essential to overcome the common negative view of the error (for which the error is only a sign of a learner problem). It is necessary to make the error an integral part of the teaching and learning process. In other words, it is necessary to mediate the error.

Mediating the error means making it the subject of an educational activity, i.e., problematizing it. Putting it as part of a development process. An error indicates a contradiction in thinking process, an inconsistency not noticed by the learner. It is, then, up to the teacher to point this contradiction. Making it the gateway to a higher level awareness. However, unfavorable material conditions faced in most educational environments can prevent or hinder the error mediation.

Studies conducted by (Vygotsky et al., 1934) indicate that the stimulus of the cognitive development of learner, to obtain solid and deep knowledge, is closely related to the interaction between the individuals. Based on this assertions of Vygotsky, and for the learner cognitive development, it is desirable that there be sufficient mediation to promote the greatest possible interaction between those involved in the teaching and learning process – teachers and their learners.

It is necessary to review some considerations about learning errors, since the errors should be seen as part of the learning process. According to (Sforni, 2004), it is necessary to see the error as a moment when a situation of conflict can lead to the learning of a new concept. One negative consequence is that the error can generate a feeling of incapacity in the learner, leading him to the dropping of the algorithms subjects and consequent possible evasion of computer science courses. The teacher, once instrumented with a computational tool to support the contexts of error, may have the opportunity to contribute to the reduction of cases of dropouts, enrollment cancel and evasions. Increasing the interaction between teachers and learners is one of the strategies proposed by (Chickering and Ehrmann, 1996) when it comes to the use of computational resources in education. Faced with an error of the learner, the interaction with the teacher, through comments, can contribute to the elucidation of common problems and thus facilitate their understanding and resolution.

According to an interactionist approach, FARMA-ALG[1] (Kutzke and Direne, 2014) is proposed to be an instrument to promote the error mediation: an implementation of a framework for computer programming education which is intended to allow the teacher to view and to manipulate answers records and their relations. It presents the concept of similarity graph between answers, over which the system provides features such as: semi-automatic classification of answers, recommendation of answers for similar learner groups and different types of data visualization. With this instrument, teachers are capable of analyzing concept formation process of the learner in a more concrete way, in opposition to an immediate and empirical vision. Thus, promoting the error mediation.

There are few researches on evaluation of tools in the field of learning error mediation. The research conducted by (Moura and Peres, 2017) describes the evaluation of a tool for promoting feedback. This research consisted of analyzing the use of feedback mechanism of errors and hits through methodological referrals. The results demonstrate that the tool creates a favorable environment for learners to question, express and collaborate. The authors also verified that the feedback mechanism allowed the error measurement and accuracy have effectively helped learners and teachers identify mistakes and then act on them.

In the field of studies on methodologies of use of these tools, the research of (Garcia and Direne,) have great relevance because it proposes a generalist methodology based on processes for the successful accomplishment of learning sessions, which are applicable for teachers and learners.

3 EVALUATION OF INTERACTION IN LEARNING ERROR MEDIATION

Although FARMA-ALG promotes the interaction between teachers and learners, there is a need for studies that allow us to state how the result of this interaction contributes to both. When evaluating FARMA-ALG, it was verified that, although its effectiveness as a tool that promotes the mediation of error has been proven, the amount of interactions between teachers and learners was extremely low. This is due to the

[1] http://farma-alg.com.br

lack of concise documentation and a specific methodology that guides teachers and learners about the resources available in the tool. Among the resources, the possibility of interaction between the teacher and the learner in situations where the learner incurs an error during the resolution of an exercise is highlighted. In order to provide the best possible use of the resources based on the social-interactionism proposed by FARMA-ALG, a study was carried out on the activities of the teacher when using the platform and, based on this information, a methodology was proposed that promotes the interaction .

A computer based environment that promotes mediation through error will only have its goals fully achieved if teachers and learners effectively utilize the interaction features offered by the tool. No matter how efficient the mechanism of sending comments and messages, if the teachers does not use them, the social interactionist intention of the tool becomes null. Seen in this terms, its use becomes restricted only to the functional aspects of creating and making available specific learning objects for teaching algorithms. Even if the teacher have the resources to visualize and manipulate the answers through the Similarity Graph, the real interaction with his learners will only happen if there are messages and comments.

According to (Hannafin, 1992), there is a lack of a guiding structure on how the teacher should use digital technology tools to achieve improvements in the teaching-learning process. In the specific case of FARMA-ALG use, there is no method or guide that helps guiding teachers to make use of mediation feature that the tool provides. There is a need, therefore, to propose and describe a sequence of structured processes aimed to the teaching practice with the purpose of guiding the teacher in order to achieve effectively mediation.

3.1 Methodology of the Study

To support the development of an effective method, it was necessary to define some objectives, practical studies and analyzes. For the development of the research, the following actions were foreseen:

- define the universe of research;
- perform critical analysis of interaction messages;
- perform statistical analysis of comments.

Data from answers of 229 students who submitted 8,887 responses, collected between 2015 and 2016 from seven classes of Algorithms and Data Structure I, from two universities, were analyzed. Three groups were from the year 2015, totaling 118 students from two universities who submitted 4,854 answers to questions applied by two teachers. Four classes were from the year 2016, with 105 students from a single university, which generated 4,033 answers to questions applied by four teachers. All classes whose answers were collected are from the initial phase of the computer science courses. The objective was to evaluate the greatest possible number of answers and interactions between teachers and students who used FARMA-ALG. Relationships as percentages of correct and incorrect answers, answers that received interventions through teachers comments, student scores and number of attempts were analyzed . Through this analysis, the objective is to detect behaviors that can show how and at what level the use of FARMA-ALG influences the results. Based on this evaluation, enough information was obtained to analyze the effectiveness of FARMA-ALG as a tool to support teaching practice in algorithm teaching.

Was tried to find out, for example, in what types of questions students find greater or lesser degree of difficulty and what are the most common mistakes. An important item was the analysis of the relationship between the answers that received some kind of intervention by the teacher and the number of attempts submitted by question. The interaction between students and teachers was verified in only 82 answers (1.93%) that received comments from the teacher, a fact that may indicate a lack of time for teacher follow up and send comments to all students who made mistakes in their answers. Another explanation for the low level of interaction was the nonexistence of a method that guides both teacher and student during the use of FARMA-ALG.

The answers that received most comments from the teacher were those that presented some logic error, which totaled 27 answers, or 35.53 % of the total. Next, the questions that contained user dialogues (unspoken in the statement) and output errors, with 18 answers (23.68%). Problems with syntax appear in nine answers, representing 11.84% and as a consequence, some of them caused five compilation errors (6.58%). Some students submitted seven answers (9.21%) whose solution was based on trial and error mechanisms, with no guarantee that the answer would be correct.

From the total of 82 answers to which the teacher made some intervention, 71 were incorrect and 10 were correct. In 46 of them (64.78%) the students made advances, being able to identify and correct the errors. On the other hand, 25 responses (35.22%) remained incorrect even with the teacher intervention. Although the number of questions that were not completed was high – even with the teacher help – it is noticeable the improvement in the performance of the students who got help. From the 25 answers for which

students did not continue the development of resolution, teacher interaction contributed to the fact that almost two-thirds of the answers that were wrong were corrected.

The analysis were also performed using descriptive and inferential techniques. The data of interest for the statistical analysis were:

- the number of attempts until the first intervention;
- the number of attempts since the first intervention, until the correct response;
- the time the teacher took to complete the first intervention;
- the time, from the first intervention, to the correct response.

In the descriptive analysis, for the aforementioned datasets, means, standard deviations and coefficients of variation were compared. In the inferential analysis, the same data were submitted to statistical tests to compare means to validate or not, the results observed in the descriptive analysis.

A reduction of 46% in the number of attempts was detected after the first teacher intervention. In contrast, there was an increase in the time spent by the student to respond correctly after receiving help, which suggests that, properly instructed and guided, he went from an earlier state of "trial and error", to more grounded answers. Considering the results of the studies, was verified the need to prepare documentation, with a concise and replicable method, that can help teachers and students that use FARMA-ALG, so that all their social interacionist potential is effectively achieved.

4 METHOD PROPOSAL

The use of a tool such as FARMA-ALG requires organization and planning from teacher, so that classes can be efficient and produce the desired result. The functions and activities that the teacher must perform for the effective use of the tool, and are part of the proposed method, are listed below:

1. Identify which course content will be taught;
2. Teach the classes using the prefered method;
3. Elaborate subjects related to Learning Objects, containing: a) Name and b) Description;
4. Edit Learning Objects, creating: a) Introduction; b) Exercises; c) Questions; d) Test cases;
5. Correct exercises that was proposed in FARMA-ALG;
6. Identify learners with difficulty levels who require intervention;
7. Establish interaction with these learners through comments and messages;
8. Follow-up evolution of learners after intervention.

The activities listed above are essential for the effective use of FARMA-ALG. However, they are not yet organized into a structured way that permits a methodology that can be replicated. Special attention should be given to corrective activities, identification of learners with difficulties, interaction and follow-up. In this section, the processes of the methodology must contain to contemplate the needs to guide the teacher in a successful implementation of interactionist model, implemented by FARMA-ALG platform, are described.

The activities are distributed among four phases, as follows:

1. Planning;
2. Elaboration and providing;
3. Evaluation;
4. Interaction and mediation.

In this model, activities of each phase must be completed in order to advance to the next, according to description of Figure 1. The structure provides an iterative mechanism, in a manner that the teacher and learners (professor and students, as in the figure) can go back to previous phases and use the information to improve activities and achieve the proposed objectives.

The objectives of each phase and the products to be delivered are listed in Table 1 and are detailed in steps in the following sections.

4.1 Planning

The main goal of the planning phase is to define what are the learning objectives that the subject should offer. These objectives describe what concepts and skills learners (students) should know and understand to be able to analyze problems, propose solutions and implement them. This phase is subdivided into three stages, in which the teacher (professors) will identify the needs and requirements, define what the learning objectives will be, and analyze how the use of the available computerized structure should be.

Step 1: Identification of Needs and Requirements.

1. The skills that learners must acquire in completing the proposed activities should be identified. A good basis for the choices is the syllabus of the course, usually provided by the course coordination, as well as its pedagogical project.

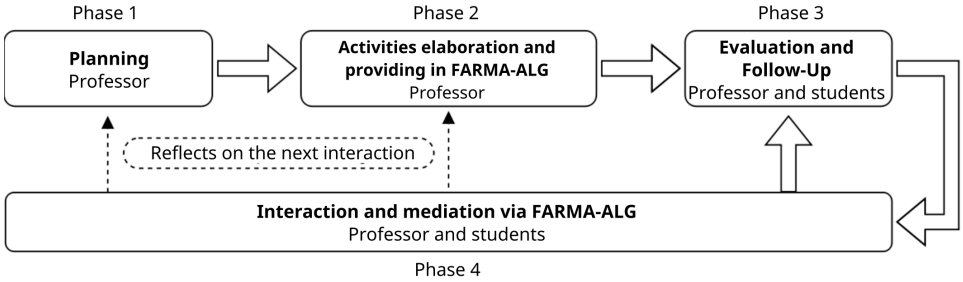

Figure 1: Phases of method.

Table 1: Objectives and products of phases.

Phase	Phase objective	Phase product
Phase 1	Definition of subject objectives	Teaching plan
Phase 2	Learning Objects Elaboration and providing in FARMA-ALG	Learning Objects containing exercises and questions
Phase 3	Evaluation, correction and identification of difficulties	Report pointing out the main difficulties of learners
Phase 4	Interaction and mediation with learners	Intervention with learners and appropriateness of exercises

2. The programming languages to be used must be the same as those which FARMA-ALG supports. Based on this information, the teacher should indicate to learners a reference guide of the adopted language in order to solve any basic syntax errors.
3. As the subject requires high level of abstraction and cognition skills of aspects about logic, it is interesting to carry out a pre-evaluation in order to diagnose eventual discrepancies of knowledge.

Step 2: Defining Learning Objectives. Based on results observed in diagnostic evaluation, in previous step, the following steps should be performed:

1. Taking the list of competencies obtained in Step 1, identify the skills that the learner must acquire at the end of the assessment.
2. According to the skills identified in the previous step, the contents that must be contained in the Learning Objects are defined.
3. Write, based on the previous steps, a formal list of learning objectives.

Step 3: Analysis of the Feasibility to Achieving Learning Objectives using FARMA-ALG.

1. Evaluate all learning objectives and identify, according to the complexity level of each one, which can be transformed into Learning Objects in order to make it available in FARMA-ALG.
2. Objectives that do not fit the above possibility should be treated with an alternative platform approach.

4.2 Elaboration and Providing

At this stage the teacher (professor) will, based on the subject syllabus, develop Learning Objects that will be available as activities in FARMA-ALG. These activities are compounded by algorithm questions, organized into lists of exercises whose difficulty level gradually increases. At the three steps that comprise this phase, the teacher will elaborate the activities, verify the adherence of the activities to the proposal and resources offered by FARMA-ALG, and define the work plan with the schedule of sessions.

Step 1: Choice of Exercises.

1. According to what was achieved in the definition of learning objectives in Step 2 of the previous phase, select the content that will be worked on.
2. Establish how many exercises will be required to achieve the goal, according to the results of the pre-assessment. Define which exercises should be included in the first list, based on the pre-evaluation.
3. Define in how many lists the other exercises will be divided and how will be the distribution among the lists, according to the difficulty of the exercises. Each list should contain exercises whose difficulty allows learners (students) to be able to

solve them, even if they need some kind of help.

Step 2: Elaboration of Learning Objects.

1. Turn each exercise into a Learning Object compatible with the FARMA-ALG prerequisites.
2. Distribute the exercises into lists according to the amount of levels the teacher has defined as necessary for the learner to successfully complete a list and be prepared for the next one.

Step 3: Schedule Elaboration.

1. Elaborate a schedule of online availability of each list of exercises, according to the progress of the subject in the classroom.
2. Define the accomplishment of activities according to the order of lists of exercises, their duration and the due date in which they should be answered. To do so, it is necessary to revise the availability of time of teachers, monitors and learners.
3. Establish deadlines for resolution of proposed exercises.
4. Indicate who will be the instructors of the subjects and inform the class.

4.3 Evaluation

At evaluation phase, the teacher (professor), together with the tutor, will correct the answers of exercises submitted by learners (students) in FARMA-ALG. During correction, it is critical to identified the main difficulties faced by learners. At the end of this phase, a report should be generated indicating which aspects were presented as difficulties in solving the exercises.

Step 1: Preparing for the Session.

1. Compose a FARMA-ALG operating instructions manual and make it available on the platform, preferably on the home screen. It should state the technical hardware, software, and network requirements for users to have access to.
2. Publish the periods in which each exercise list will be available.
3. Notify learners and tutors, via e-mail, the address to access the platform, as well as the necessary procedures to register and enroll in the course.
4. Define how learners will get support in case of problems with the platform.
5. Publish Learning Objects so the enrolled learners can access the lists of exercises and solve the proposed questions.

Step 2: Session Development.

1. Before actually releasing the platform for use, perform connection tests to diagnose any problems in a timely manner to solve them.
2. Grant access to FARMA-ALG to learners, only to the list of exercises whose content was previously developed in the classroom.
3. Periodically, monitor learner participation, checking if they are getting access to questions and submitting their answers without any kind of problem.

Step 3: Evaluation of Responses During Submission Period.

1. On the FARMA-ALG main panel, check the following items:
   - Write down the number of incorrect answers.
   - Check for comments and messages sent by learners, directed to the teacher or tutors.
2. In the 'Graph Manipulation' Menu, with the appropriate use of the available filters, perform the following actions:
   - Set up the filters in order the search carry out for a question, of a class and that is in a certain category of error. i.e.: Question: *Triângulo de Pascal* (Pascal's Triangle); Class: Alg-2016/1-ci055-B; Category: *Saída* (Output). See example in Figures 2 and 3.
   - Identify the incorrect answers with the highest degree of similarity between them.

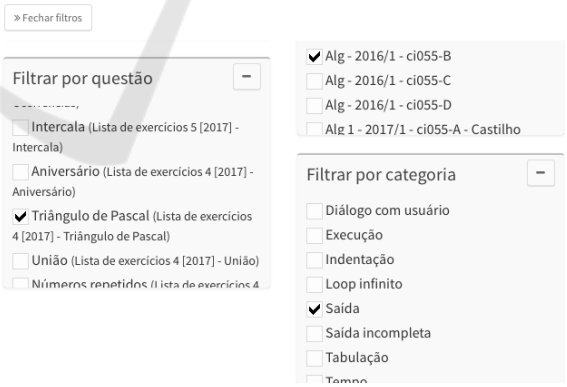

Figure 2: Search using filters.

3. Using the 'Timeline' Menu, perform a procedure similar to the previous step, in order to identify responses with the highest degree of similarity as possible.
4. Additionally, use the 'Search' features to find error patterns.
5. Use, if necessary, the 'Tags' feature, which allows you to select responses with certain types of errors, as shown in Figure 4.

Figure 3: Answers found.

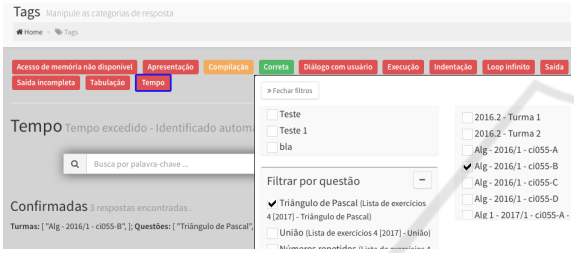

Figure 4: Search result for error tags.

4.4 Interaction and Mediation

At the fourth and last phase, interaction occurs between learners (students), tutors and teachers (professors). As questions are being answered, teachers and tutors should identify learners who have encountered difficulties. The observation of similarity in incorrect answers, carried out in the previous phase, should be used to subsidize this task. Then, teacher and tutor should promote interaction with the learners by sending specific comments about the most common mistakes made in the attempts to solve the exercises. If necessary, in addition to talking with the learner, in order to understand their difficulty and to assist them, the appropriateness of the exercise may be necessary.

Step 1: Identify Learners who Need Support.

1. Read the messages and comments sent by learners. If they have sent them before the teacher, they are asking for clarification.
2. Identify learners who have made mistakes, according to the following criteria:
   - Level of progress in solving questions of the current exercise list. The lower the progress bar, the greater the possibility that the learner is experiencing difficulties and in need of help.
   - Number of attempts per Learning Object. Exercise lists with large numbers of attempts may indicate that learners are not sure their answers are correct.
   - learners who made mistakes very similar to those of other colleagues. The data obtained in Step 3 of the previous step are used for this purpose.

Step 2: Identify Questions that Learners had Most Difficulty Solving.

1. Identify the questions that got the most incorrect answers.
2. Categorize the incorrect questions by types of errors.

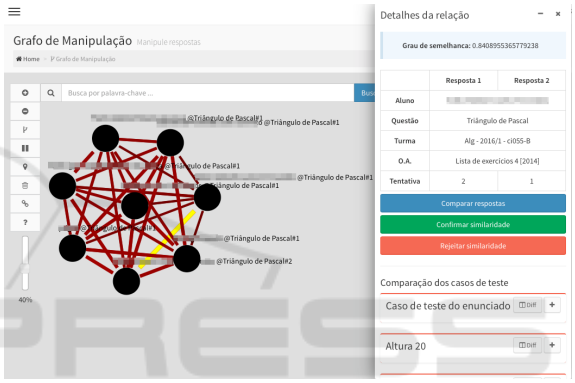

Figure 5: Graph and similarity result details.

Step 3: Intervention with Learners.

1. Respond to messages and comments from learners who have already submitted them.
2. Send messages or comments to groups of learners with similar difficulties on certain questions.
3. Send individual messages or comments to learners who have a specific difficulty.
4. Monitor learner performance after intervention.
5. Complement the intervention with additional messages and comments, if necessary.

The evaluation of interaction in learning error mediation in previous section made it possible to observe that FARMA-ALG is effective in its purpose of remedying an erroneous answer through the teacher intervention. Yet, the number of recorded interactions was low. The method proposed in this section was developed based on the observations of this study.

5 CONCLUSIONS

For FARMA-ALG evaluation, descriptive and inferential techniques and methods were used. A reduction

of 46% in the number of attempts after the learner-teacher interaction was confirmed. The intervention of teacher is, therefore, a great contribution so that the learners can solve their doubts and progress in solving the problems proposed.

Regarding the effectiveness of FARMA-ALG, it was verified that its use promoted an increase in the number of correct answers by about 7.5%, considering the performance of learners, from one semester to the next. However, it was found that even so, the percentage of incorrect answers remained high, close to 70% of all answers. Most of the incorrect answers occurred in questions of the first exercise lists, which indicates possible lack of mastery of the basic principles of the programming languages used. This assumption is based on the fact that most of the errors detected were of compilation and unexpected output.

It was observed that the interaction level, verified by the amount of messages and comments sent by the teachers was extremely low, reaching only 1.93% of the total responses. Despite the small number of interactions, it was verified that they were essential for the learner to progress in solving the exercises. However, it was found that the high number of attempts on the most basic questions can be reduced by anticipating the intervention.

The questions that received comments and messages from teachers were carefully checked. A large number of consecutive attempts were made by the same student for a single question, which indicates a possible "trial and error" situation. Faced with this picture, it was observed that the teacher comments always aimed to guide the learners about where they were making the mistakes and how to circumvent them. The teacher intervention was successful in verifying that the students who received a recommendation succeeded in about 65% of the total number of questions in which they had made mistakes.

There was a reduced amount of interactions, due in large part to the lack of a method that guides the teacher in his activities with FARMA-ALG. The simpler and easier the use of a platform, the more effective the results of its adoption. However, even if the aspects of usability are visible and favorable, there are others that, although very important, are not explicitly stated and documented in FARMA-ALG. As an example, there is the error mediation feature through interaction, one of the main differentials of the tool.

The lack of a method for interaction, as seen from the results of the evaluation of interaction in learning error mediation, can compromise the breadth and effectiveness of the proposed interaction actions. Formalizing and making available a method that works as a guide in all phases of the teaching process and considers interaction resources, can benefit teachers and learners. Therefore, it was proposed that all the social interactionist characteristics of FARMA-ALG, can be fully exploited. Considering that this is an ongoing research, there are currently no results on the effectiveness of the proposed methodology. There is, therefore, a need to conduct new researches that evaluates the outcome of the proposed methodology implementation.

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