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Open Educational Resource for Studying Algorithms and Programming Logic: An Approach to the Technical Level Integrated with Secondary School

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Abstract. The teaching and learning of programming has proven to be a challenge for students of computer courses, since it presents challenges and requires complex skills for the good development of students. The traditional teaching model is not able to motivate students and arouse their interest in the topic. The tool proposed herein, the REA-LP, aims to facilitate the study and retention of content related to the discipline of programming logic at the technical level by presenting its content through various types of media, in addition to allowing students to actively participate in the construction of their knowledge, favoring engagement and motivation. From the results of an empirical study with 39 students, it can be concluded that the tool was very well accepted, being effective in facilitating and assisting participants in their learning, motivation, and interest in classes, mainly due to the way in which the content is presented by REA-LP.

Keywords: open educational resources, algorithms, programming logic, technical education.

1. Introduction

In general, teaching programming is one of the greatest challenges for students of Computer Science and related courses, at higher and technical levels, leading students to dropout in some cases. For Medeiros (2019), there are several triggers that cause dropout. He highlights the difficulties with programming logic (PL) and the syntax of the languages used in teaching. In 2000, Borges (2000) argued that the traditional teaching model is not capable of motivating students and making them interested in the topic. In this context, Bennedsen and Caspersen (2019) point out a world average of evasion and failure of about one-third of the students. In Brazil, Watson and Li (2014) report a 55%

failure rate; similarly, Medeiros (2019) reports a failure and dropout rate of 45.6%. According to Santiago and Kronbauer (2017), one of the factors that leads to poor use of the discipline is the poor methodology used in the classroom.

The profile of the technical education student integrated to the secondary school in Brazil corresponds to that of students who want to have access to the job market in a shorter period, as well as to have a first contact with the area, thus evaluating their aptitude before entering higher education.

According to Lévy (2007), the school is an institution that for five thousand years has been based on the speaking and dictation of the master and, for four centuries, on the use of printing. From the integration of Information and Communication Technologies (ICT), there is, therefore, a perspective of modernization of a more than millenary teaching model. For Sancho and Hernándes (2008), there is a need for the actors involved in education, such as teachers, principals, and specialists, to review their way of teaching and to direct greater attention to how the young people of this century learn. The traditional teaching system does not consider the heterogeneity of students, their differences in the way of learning, skills, and difficulties, especially in content in which skills and logical reasoning are extremely necessary (Barcelos *et al.*, 2009).

Current students of technical education integrated to secondary school are considered digital natives. For Prensky (2001), digital natives represent individuals who were born and grew up with new digital technologies, thus having a natural fluency in handling these technologies. Hence, the use of an open educational resource (OER), as a technological alternative for teaching, can be beneficial for studying algorithms and programming logic, considering the use of new technologies in education and adaptation to the current profile of students of computer courses, which are usually more connected and technologically engaged students.

Some factors justify the research on screen. First, teaching and learning the discipline of algorithms and programming logic has proven to be a challenge for many years. Jenkins (2002) relies on three main causes for poor student performance: lack of problem-solving skills; pedagogical methods inappropriate to the learning style of students; programming languages used in teaching have syntaxes that are more suitable for professionals rather than for beginners. In addition, in their systematic literature review, Medeiros *et al.* (2018) also point out difficulties with solving, executing, and evaluating algorithms, in addition to behavioral problems, such as motivation, engagement, time management and lack of trust. Second, the changes in the Brazilian secondary education, created from the transformation of Provisional Measure 746 of 2016 (Brasil, 2016a) into Law No. 13.415/2017 (Brasil, 2017), brings the possibility of offering the teaching of the programming logic discipline in all Brazilian schools, by allowing apprentices to choose, among the areas of interest, professional education, thus increasing the demand for teaching PL.

Finally, 75% of the learning objects (LO) developed to help teach PL, as pointed out by Silva *et al.* (2015a), focus on higher education, with only 3% focused on the technical level. In addition, most LOs present programming languages that are not very didactic and in a foreign language, not including Brazilian students; there is also a lack of tests and validation in the classroom.

This research therefore aims to present an OER with the purpose of facilitating the study and retention of the content related to the PL discipline at a technical level. The proposed environment is expected to allow students, to actively participate in the construction of their knowledge by presenting the content through multimedia resources, making them more motivated and engaged. After the development of the tool, an empirical study was conducted to assess the perception of use and acceptance of the tool, as well as student performance in the activities proposed. Furthermore, its pedagogical characteristics were evaluated according to the Constructivist Learning Theory and the Multimedia Learning Theory (MMLT).

As a direct contribution of this study, we highlight the availability of the REA-LP as a responsive website, available to students and professors interested in the area.

2. Background

2.1. *Learning and Teaching Challenges*

The introductory courses on algorithms and programming logic aim mainly to teach problem-solving skills using computational algorithms. However, the difficulties and challenges that teachers and students face in with these subjects are evident, despite being the basis of Computer Science courses and the like. This makes the LP discipline one of the existing bottlenecks in computing courses, usually showing high rates of failure and dropout (Bennedsen; Caspersen, 2019). Medeiros *et al.* (2018) point out various difficulties faced by students, such as problem formulation and solution, algorithmic thinking, the abstract nature of programming, solution, execution, and evaluation of algorithms, but also behavioral problems, such as motivation and engagement. In addition, Medeiros (2019) highlights English language as one of the obstacles encountered by Brazilian students. For Pereira Júnior *et al.* (2005), the diversity in the learning styles of students, added to overcrowded classes, create another obstacle for the effective learning of the discipline.

Barbosa *et al.* (2011) argue that poor performance and lack of motivation cause disinterest in students, who eventually consider the discipline as a barrier to their training, feeling discouraged from continuing the course. According to Almeida *et al.* (2002), the poor performance caused by the difficulties becomes a vicious cycle, because, when perceiving their lack of evolution, students feel increasingly unmotivated, and their performance increasingly worsens.

The greatest teaching challenges observed by the authors of this research throughout their teaching careers, as regards the technical school that targeted by the intervention, are: (i) the motivation of students with the discipline, since, in general, there are few interested in programming disciplines, even though they have chosen the technical course in informatics among other options; (ii) great deficiency with basic mathematics, notion of logic, interpretation, and problem-solving; (iii) students are often unable to understand and to apply the concepts of problem-solving using algorithms, as they do not understand the problem or cannot use the necessary mathematics knowledge for its solution.

2.2. *Programming Language Selection*

According to Robins *et al.* (2003), introductory programming courses devote a considerable time to teach particularities of specific programming languages. For Pears *et al.* (2007), languages such as Java, C++, and C, are among the four most used according to the Tiobe index (2022) of programming languages. However, these languages were not developed for educational purposes. Still, according to these authors, these languages are very detailed and impose notations that are not related to learning to think algorithmically.

In Brazil, according to Silva *et al.* (2015b), the use of pseudo-languages in the Portuguese language seeks to focus on aspects of programming logic as opposed to language syntaxes, as well as reducing the language barrier imposed by a foreign language. In this sense, the IDE VisuAlg with the Portuguese language was chosen for this research, as it has the main resources for teaching programming logic.

2.3. *Open Educational Resources*

The concept of an OER describes any educational resource openly available to any educator and student, without the need to pay license fees or royalties. Its transformative power lies in the ease with which its contents can be shared over the Internet after being digitized (Butcher *et al.*, 2015). In their analysis of the perception of a total of 2144 lecturers from US higher education institutions regarding OER, Allen and Seaman (2014) observed that most participants rated them as equal or superior to traditional resources in terms of cost (97.9%), content (91.2%), ease of use (88.1%), effectiveness (84.6%), and quality (73.6%). The studies by Farrow *et al.* (2015) and Pitt (2015) indicate that OER can indirectly improve student performance by increasing their satisfaction, engagement, and interest in subjects.

In their study with 21822 students enrolled in various undergraduate courses at the University of Georgia, Colvard *et al.* (2018) conclude that students perform better in courses whereby OERs were used to the detriment of traditional/commercial materials, and that failing grades and dropout rates have decreased, especially for students in vulnerable situations. For Wiley (2006), it is unacceptable to allow this scarcety of education opportunities to continue when educational materials are so abundant and their distribution and duplication cost so low.

According to Seabra *et al.* (2014), the fact that OERs explore different media, such as videos and audios, among others, can provide greater gains by meeting different learning styles and intelligences of students. For Biesta (2017), the OER movement meets the “new theories of learning,” constructivist and sociocultural theories, which shift the focus from teaching activities to students, the target audience of these resources.

To make an OER legal, it is necessary to license the content to make it available. For copyright protection, copyright licenses are used, such as Creative Commons (CC), General Public License (GPL) and the GNU Free Documentation License (GFDL). According to Atkins *et al.* (2007), Creative Commons is of great value to OER.

2.4. *Learning Theories*

According to Henrique *et al.* (2015), learning theories seek to explain how learning occurs and should therefore be used for developing and evaluating educational software. In their systematic review of the literature on educational software, the authors point out that only 27.9% of their sample used some learning theory, the most used being the theory of constructivism by Piaget. The same can be observed in the works by Wu *et al.* (2012), Ribeiro *et al.* (2015) and Silva *et al.* (2015b).

For Gama (2007), in constructivism, learners are active beings and co-responsible for their learning, capable of formulating new ideas, answers and hypotheses, reviewing their thinking, and presenting a better solution to the problem. The teacher, in turn, plays the role of encourager, facilitator and creator of situations that provide opportunities for constructing the knowledge of their students. Also, according to the author, to evaluate a constructivist environment, it is necessary to test the aptitude, interest, and achievement of the student.

The concept of multimedia learning for Mayer (2005) is learning by the combination of images and words. The first refers to static images (illustrations and photos) or dynamic (animations and videos), while words refer to spoken speech (audio) and the written part (text). For the author, people learn more with the joint use of images and words, than with the isolated use of one or the other.

One can test the theory of multimedia learning, according to Mayer (2005), by ascertaining its principles:

- Modality: learning occurs more easily if the images are presented together with the narrated text.
- Signaling: learning is more efficient if there are hints in the text of what should be analyzed in the images.
- Contiguity: learning is facilitated when images and corresponding words are presented next to each other.
- Segmentation: learning is favored when a message is presented in a segmented way.
- Anticipation: Learning occurs more easily if the content is presented and, only later, detailed.
- Coherence: Individuals learn better if words, sounds and images that are irrelevant to the subject at hand are not presented.
- Redundancy: Excessive repetition of information causes cognitive overload and hinders learning.

Furthermore, according to the author, it is also necessary to assess whether the participant working memories, visual and/or verbal, are not being overloaded, as well as whether the processing channels, verbal/auditory and visual/pictorial, are equally stimulated.

2.5. *Related Works*

Since the emergence of the term Open Educational Resources, its scope and availability has been expanding, with new OERs being created throughout the world. Based on the theoretical foundation of this research and from the mapping of OERs aimed at programming teaching, some OERs identified aim to help programming teaching and learning, three of which are presented below. In this research, all the educational resources developed for use in teaching and learning and that are openly available to educators and students are considered OERs, according to the definition by Butcher (2015).

The "REA-AED," by Silva and Seabra (2018), seeks to help students learn algorithms and data structures. It consists of a website with a simple and intuitive graphical interface, with modules presenting the course content using C language and Portuguese pseudocode. The resource was evaluated by a case study with 55 undergraduate students in computer science, and the results showed that the students considered that the OER helped them to understand the contents of the discipline and provided a differentiated learning environment. The resource can be accessed at:
`https://gabrielbueno072.github.io/rea-aed/index.html`

The "Turing Project," by Silva *et al.* (2020), consists of an OER for teaching programming with an RPG game, involving puzzles, missions, and combats. The game, available in Portuguese, uses the C# programming language and pseudocodes. A study carried out with 19 users of higher education in computing and other courses pointed out that the game provided good experiences, reflecting positive impacts on learning by those students. The game can be downloaded from:
`https://github.com/josivanSilvaCodes/Turing_Project_Alpha_Demo`

The "Spielend Programmieren Lernen" is a MOOC proposed by Löwis *et al.* (2015), a program of the Hasso Plattner Institute, Potsdam – Germany, aimed at teaching the basics of Python programming to children and teenagers. It consists of a program with tutorial videos, quizzes, and programming exercises. A study was carried out with 7400 students of various ages, 2523 of whom were graduating. The MOOC uses Bloom's Taxonomy in its content. A high dropout rate can be observed, but it was well received by the participants, with the majority stating that they would recommend the course to others. The MOOC can be accessed at:
`https://open.hpi.de/courses/pythonjunior2015`

Choosing an OER for use in a course can be a difficult task, but some characteristics can be decisive for that choice, such as the language in which the tool is presented, as well as the programming language used. Choosing an OER and a programming language in the native language of students eliminates the barrier of a foreign language. Structured programming languages tend to be more didactic than object-oriented ones. It is important to note whether the OER was developed for the appropriate level of the students, i.e., infant, technical or higher, as well as whether learning methodologies and theories were used in its development and assessment. The type of evaluation and whether the resource was evaluated can also be decisive in the choice.

From the mapping of OERs aimed at teaching programming in the literature, resources notably tended to use programming languages made for the professional environment, such as Java, Python and C, languages that are not didactic and that have syntaxes complex for beginner students, in addition to their all being in English, creating a language barrier to Brazilian students. The OERs in question were mostly developed for higher education. There is, therefore, a lack of works directed to secondary and technical education.

Hence, one of the differentials of REA-LP is to present its content by the pseudo-language "Portugol" (structured Portuguese), using VisuAlg, a tool developed for academic environments. VisuAlg provides several didactic features, such as the variable visualization area and the possibility of executing the algorithm step by step or with reduced time. In addition, it has a simple syntax in Portuguese, eliminating the language barrier of a foreign language, allowing students to focus on developing their algorithmic thinking.

Another differential of the REA-LP is the presence of the first two modules – fundamental mathematics and introduction to logic – considered prerequisites for an effective learning of the discipline of algorithms and programming logic. The topics mentioned are presented as a review of essential logical-mathematical content, and as an anticipation of some content that a secondary school student would only study in later years.

The main characteristics defining REA-LP as a resource aimed at secondary and technical education are:

- Use of structured Portuguese (VisuAlg) as a programming language, in contrast to languages such as C and Java, which are more common in higher education.
- The course syllabus at a technical level does not present more advanced data structures, such as lists, stacks, queues, and trees.

3. Method

3.1. *REA-LP*

REA-LP is an educational tool presented in a website, and its interface was planned and developed to provide the user with a simple and objective interaction experience. Its development main guideline was the creation of a tool rich in content, aiming to provide a pleasant experience in the study of algorithms and programming logic. The tool developed in this research can be accessed at the following link:
`https://diegoefp.github.io/REA-LP/index.html`

The resource has 11 modules or classes, the first two, Fundamental Mathematics and Introduction to Logic, being considered prerequisites for the effective learning of the LP subject. Its objective is to provide content to support a review of logical-mathematical concepts. The mathematical contents presented in module 1 (Fundamental Mathematics) are based on the work of Baldwin *et al.* (2013) and Ralston (1984). The contents of the second module (Introduction to Logic) are based on the Introduction to Logic subjects present in higher-education computing courses. In this module, the concepts of Propositional Logic and Truth Table are presented.

The following nine modules are based on the syllabus of the Algorithms and LP course for computer courses at a technical level. Its contents are based on the booklet developed by the authors of this work and by two other lecturers of the discipline, also considering the guidelines of the K-12 Computer Science Framework Steering Committee *et al.* (2016). Modules 1 to 9 are illustrated in Fig. 1.

By clicking on the icon or the title of the module, the student will be taken to its respective module. When accessing it, the user will find a banner with its title and a brief description of its content, followed by the class itself. Each class or module can be subdivided into sections. All the modules have learning objects, as well as multimedia resources in the form of text (Fig. 2a), static images (Fig. 2b), dynamic images (GIFs),

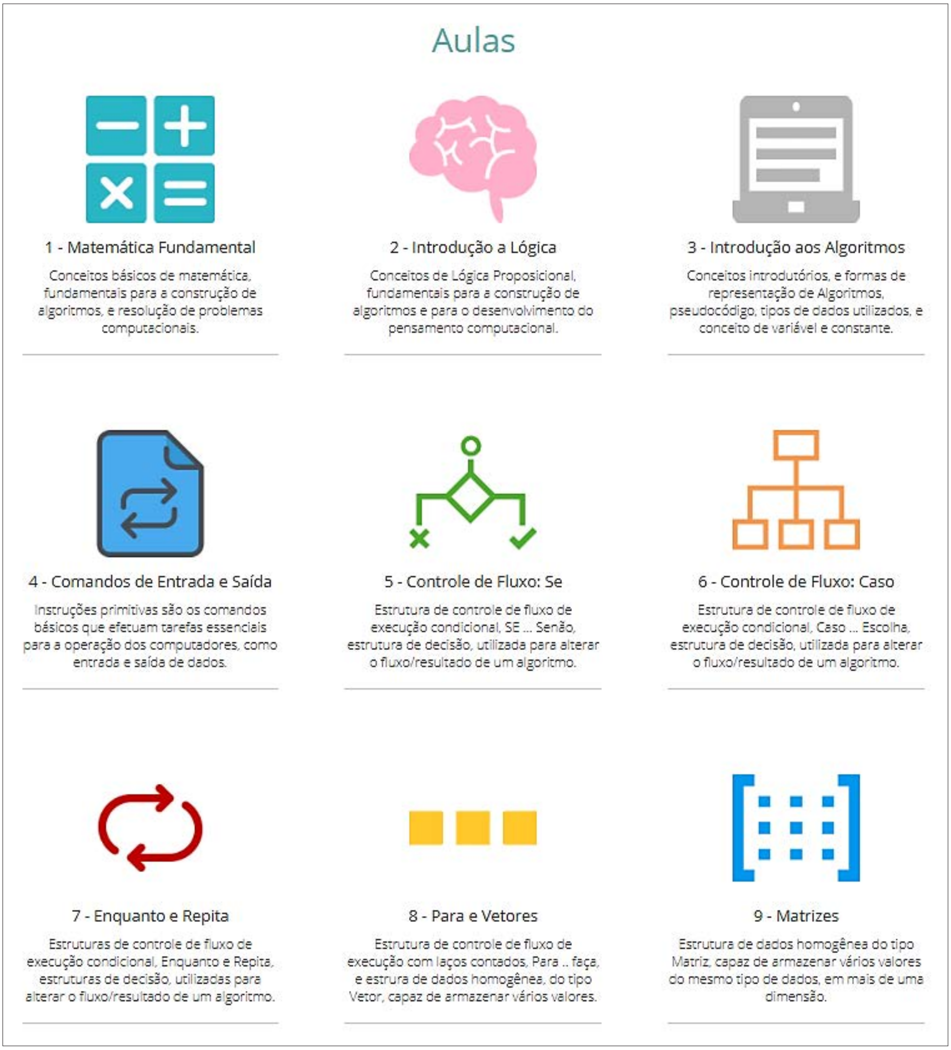

Fig. 1. REA-LP modules. Source: The authors.

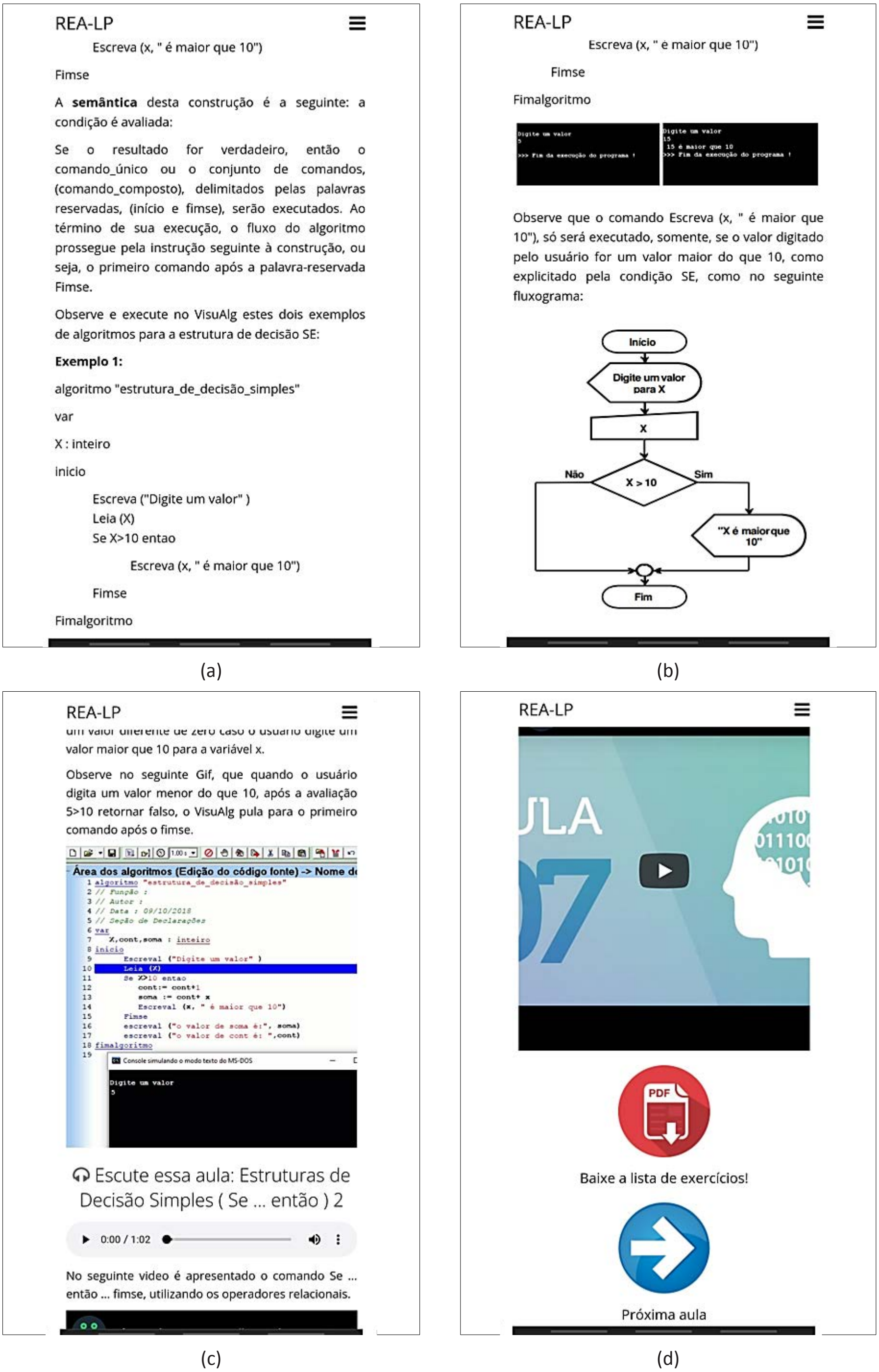

Fig. 2. Multimedia learning objects. Source: The authors.

audio (Fig. 2c) and video (Fig. 2d), contemplating various forms or learning styles. At the end of each module, a button can be found to download a list of exercises related to the module and a button that takes the user to the next class (Fig. 2d).

For Mayer (2002), multimedia messages are the vehicles for delivering information, providing the acquisition of information and the multimedia learning process, acting in the construction of meaning and knowledge. For the author, students learn better when words and images are presented together, creating the opportunity to build mental, verbal, pictorial models, and the connections between them, which would not be possible with textual resources alone. Also, according to the author, students who use multimedia resources, such as texts, illustrations, narrations, and animations, perform better on tests when compared to students who use only one type of resource. When these resources are presented at the same time, students are more likely to be able to build mental and memory representations and connections between them.

According to Kenski (2003), digital ICT and multimedia resources promote different ways of achieving learning, by providing new possibilities for interaction, communication, and access to information. The tool was developed to include multimedia resources in the following ways:

- **Textual representation:** The material in text form is based on bibliographic materials referenced in the footer of each module, and were developed aiming at simplicity and objectivity, regarding the transmission of the content to the student.
- **Static images:** The static images show examples, present screen outputs of programs, and even make the examples more fun and engaging.
- **Dynamic images (GIFs):** Dynamic images are a differential of an educational tool in the form of a website, as they have the attribute of movement, and can be used to show the change of state, for example, the changing the values stored by a variable, or how the execution flow of a given algorithm takes place, which can be watched several times.
- **Audios:** The audios represent another differential of an educational tool in the form of a website, as they allow the student to hear the explanation and/or narration of the content in question and can be played several times by the student. The audio player has a slider, allowing students to advance or rewind a recording, also having a volume control and a button that makes the audio file available for download. The audios were created so as not to be long and boring for students who listen to them, lasting two and a half minutes on average.
- **Audiovisual resources:** The videos allow students to visualize and listen to the module, through a type of media that allows customization and freedom of creation, with the potential to be a very rich learning object. The videos used in the tool, from YouTube, were chosen for the quality of their content, fidelity to the class in question and resources used to teach the various subjects.

In the footer of the pages of the classes, there is a section that contains useful links to the channels of the videos used and to the sites that can serve as additional sources of knowledge, besides the references used in the elaboration of the respective module. REA-LP was developed in a responsive way, that is, it can adapt to the different sizes and screen resolutions of the devices the user will use the tool, as can be seen in Fig. 3.

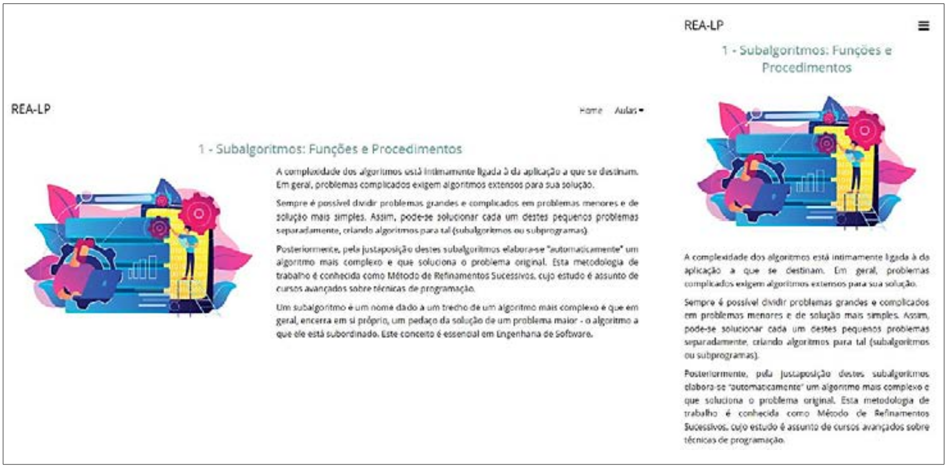

Fig. 3. Content adaptation (responsive design). Source: The authors.

The tool was developed using the Sublime Text1 source code editor, version 3.2.2 for Windows. The editor is cross-platform, with support to several programming languages, using the HTML5 markup language (HyperText Markup Language, version 5) to structure the website content, together with the CSS3 style sheet language (Cascading Style Sheets, version 3), responsible for the style and design of the interface.

Learning objects, such as GIFs (Graphics Interchange Format), responsible for dynamic images without audio, which present the execution of codes, were created using the Snagit 2020 software, which allows screen recording, editing and subsequent conversion into video or GIF. The other GIFs of the tool were created using Microsoft Power Point.

The algorithms presented in REA-LP were developed and executed using VisuAlg3, a free program for editing, interpreting, and executing algorithms. Version 2 was used for most algorithms and version 3 for codes of module 11 (Records). The audios in the tool were recorded and edited using the free audio recording and editing software Audacity4, in its version 2.4.2.

3.2. *Participants and Method Description*

After the development of the tool proposed in this research, classes of Algorithms and LP were offered to 39 students entering a school of the State of Minas Gerais, Brazil, in a technical computer course integrated with secondary school. The students interacted with the REA-LP for a semester, covering 32 class hours.

Due to the SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) pandemic, which causes COVID-19, some isolation measures, aimed at preventing the spread of the disease, have been put in place over the world. Among the measures adopted in Brazil and, therefore, in the State of Minas Gerais, among others, was the suspension of face-to-face classes in all schools. Lessons were therefore taught by the so-called TSP

(Tutored Study Plan), one of the tools of the virtual study regime created by the Minas Gerais State Department of Education. TSPs were made available to students through the Google Classroom tool, and classes were taught remotely, using Google Meet to hold meetings at a distance. Each TSP lasted for one two-month period or eight weeks, and each week a didactic material and its corresponding activity were presented. The case study, therefore, was carried out for the duration of two TSPs or sixteen weeks.

It is important to emphasize that this research followed the ethical precepts determined by Resolution 510 (Brasil, 2016b), of April 7, 2016, and that, when volunteers were invited to participate in the research, they received an explanatory text about the objective of the research and the confidential character of the information collected. At the end of the explanation, those who agreed to participate in the research signed an informed consent form.

To investigate the perception of use and acceptance of the tool, from the opinions of participating students on issues related to the use of REA-LP, two questionnaires were applied based on research by Gama (2007) and Cacho (2016): expectation questionnaire of use and questionnaire of reaction to the use and acceptance of the tool. Finally, interviews with focus groups were carried out. The questions of the questionnaire on the reaction to the use and acceptance of the tool can be viewed in Table 1.

In addition to these two questionnaires, each activity sent to the students had a set of questions regarding the use of the tool for that activity. After the classes using the REA-LP, in the last week, an extra didactic evaluative activity was also carried out, corresponding to the post-test. This activity aimed to measure the knowledge acquired, in the opinion of the participants, in the classes taught using the REA-LP, and to relate their performance to the levels of acceptance and use of the tool.

The first questionnaire, on the expectation of using the REA-LP, was applied after the presentation of the tool to the students, prior to its use in the classroom. After the 13 questions in the questionnaire, the participants answered about their level of knowledge on the topic of algorithms and LP, what they expected from REA-LP, if they had the opportunity to use an OER before this study, among other questions. The second questionnaire of reaction to the use and acceptance of the tool was applied after the use of the REA-LP in the classes, in which the students described their experiences with the tool. The 29 questions aimed to find out if students believed that there was a gain in their knowledge of algorithms and LP, if their expectations had been met and if they would use and/or recommend OER, among other questions.

Students were also asked about the presence of any flaws in the tool or if there was any difficulty regarding its use. The questionnaires on the activities had the participation of 27 students who used the REA-LP during the performance of 10 activities proposed in class, totaling 265 answers. An average of 9.8 responses per participant was observed, with an average of 26.4 students per activity. The difference in the number of participants in relation to the other questionnaires is due to the students who missed classes and/or who did not answer the questionnaires.

The interviews with the focus groups, in turn, were carried out for a deeper understanding of the level of acceptance and use of the tool, as well as the evaluation of the principles of the Learning Theory of Constructivism and MMLT. The 10 questions ad-

Table 1

Questionnaire on the reaction to the use and acceptance of the tool. Source: The authors

ID	Questions
1	Do you often use the web for studies?
2	Do you like the idea of being able to access an educational resource at home anytime, when you need it and at no cost?
3	Is the REA-LP understandable and easy to use?
4	Does the educational resource present the necessary resources for the proper study of algorithms and programming logic?
5	Regarding the motivation to use REA-LP to help the study of algorithms and programming logic, it can be considered that:
6	In your opinion, has the use of REA-LP kindle interest in the contents of algorithms and programming logic contained therein?
7	Did the modules become more interesting with the use of REA-LP?
8	Are the activities appropriate and did the use of REA-LP facilitate your understanding of the content of algorithms and programming logic?
9	Do you feel confident about using REA-LP?
10	Will you know how to use the knowledge acquired by REA-LP in future practices?
11	Has the use of REA-LP increased the level of your knowledge regarding the content of algorithms and programming logic?
12	On a scale ranging from 'very good' to 'very bad,' regarding the REA-LP, report the relevance, suitability for the content of algorithms and programming logic, and the ease of understanding the content.
13	How do you rate the visual resources provided by the tool (colors, images, buttons, screen size, text size, etc.)?
14	What types of media in the REA-LP did you use the most?
15	Of the types of media in the REA-LP, which do you believe has added the most to your knowledge?
16	Did the revision modules (Fundamental Mathematics and Introduction to Logic) in the REA-LP help your learning of programming logic?
17	Did the images and audios in the REA-LP facilitate your learning?
18	Did you ever feel overwhelmed by the information presented by the text, images, and audio in the REA-LP?
19	Does the textual information in the REA-LP present hints or signs of what should be observed in the images?
20	Are the textual information and the corresponding images in the REA-LP presented next to each other?
21	Did the dynamic/segmented images (GIFs) in the REA-LP facilitate the learning of the concepts of algorithms and programming logic?
22	Is the way the contents in the REA-LP are presented and subsequently detailed appropriate?
23	Do you believe that REA-LP presents words, sounds, or images that are irrelevant for learning the concepts of algorithms and programming logic?
24	Do you believe that REA-LP presents words, sounds, or images with excessive repetition of information?
25	Which of the electronic devices that connect to the Internet, did you use the most to access the REA-LP?
26	Would you use REA-LP again?
27	Would you like other disciplines to explore similar tools for teaching and reinforcing the content learned in the classroom?
28	Would you like to comment on the use of REA-LP?
29	Have you identified any defects and/or would you like to suggest improvements to the REA-LP?

dressed during the interviews were selected from the questionnaire of reaction to the use and acceptance of the tool. Twelve participants from the four focus groups interviewed were selected based on grade, behavior, and class participation criteria. Three students from each group participated in the interviews. As the interviews were conducted in person, some measures to prevent COVID-19 were taken. Each group was called separately, and the interviews were carried out in the school library, a large and well-ventilated place, using a round table that allowed the students and the researchers/interviewers to maintain a safe distance. In addition, all the participants wore protective masks and alcohol gel before, during and after the interview.

During the interviews, the students were asked and led to think about 10 questions extracted from the questionnaire of acceptance and reaction to the use of the tool. Participants listened to each other's responses and offered additional comments on the questions. The interviews had an average duration of 20 minutes and were audio recorded with the permission of the participating students. The transcripts of the answers were made in order to be as close as possible to student statements.

4. Results

From the information collected, it can be identified that, at the end of the intervention, approximately one quarter of the participants in the sample were female, indicating low adhesion of women to computer courses and the like. Most participants stated that they used the Internet for studies daily or at least three times a week, a behavior that was also observed in the interviews with the focus groups. This preference for using the Internet for studies is mainly due to the ease, quantity, and quality of the content available on the web. Furthermore, 100% of the participants had a smartphone and about half of them claimed to have a notebook or desktop.

Regarding OER, most students have never had contact with this type of tool, which shows that the use of OER is still very limited in Brazil and should be more widely used. The students also stated to feel confident and motivated to learn more with the use of technology, and that OER will allow the development of new knowledge, facilitating their learning, as it has diverse information, helping them to be self-taught, which is expected from digital natives.

Participants believed that the REA-LP made the way to study the content related to the proposed activities clearer, reinforcing that the existence of a didactic tool, such as OER, available for consultation at any time and free of charge, has the potential to facilitate their search for knowledge, contributing to their active learning.

A comparison between the results of the activity, expectation of use and reaction to the use and acceptance of the tool questionnaires is presented in Fig. 4.

There was an increase in the percentage of students who liked the idea of being able to access an OER to help them with their studies at any time, free of charge, surpassing the expectation that was 67.6%, rising to 90%. The students pointed out the diversity of media and the content pre-selected by the teacher, gathered in one place, as the main approval factors. In this sense, most of the participants agreed that the REA-LP was

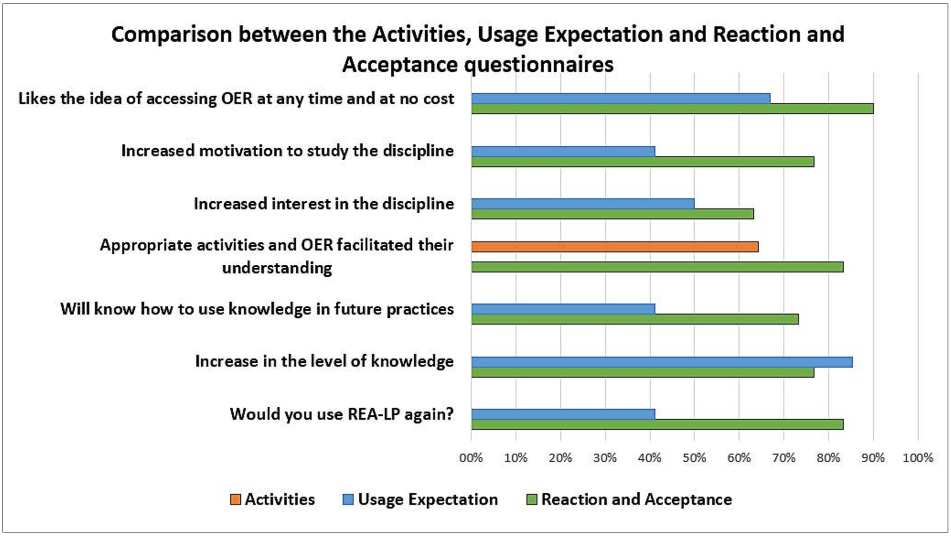

Fig. 4. Comparison between the results of the questionnaires. Source: The authors.

understandable and easy to use, and that it also presented the necessary resources for learning LP. They justified that the site had a good interface, was well planned, and organized, with the material divided and presented in a didactic way. It was also possible to observe an increase in relation to the expectation of interest and motivation to study the discipline due to using the resource.

Regarding the activities proposed by the tool, most students stated that they were appropriate, and that the REA-LP facilitated their understanding. This result is of great value for a discipline in which students learn more in practice, performing the proposed activities. Comparing with the activity questionnaire, it was possible to observe an increase from 64.3% to 83.3% among those who ‘totally agreed’ with the question. The students pointed out that the activities are compatible with the material studied and that they facilitated and helped understanding the content. Student confidence in the tool was high, and most felt safe in using it, mainly due to the ease of use and the certainty of finding answers to their questions, according to the students. Most of the participants (73.3%) also felt confident that they will know how to use the knowledge acquired in future experiences, portraying an increase in expectations that was 41.2% among those who ‘totally agreed.’ Participants commented that they will return to the tool in cases of doubt, and that the practice provided by the REA-LP enabled them to gain lasting knowledge.

In this sense, there were reports that the use of REA-LP increased the level of knowledge of participants in the discipline. However, there was a reduction in relation to the expectation of increased knowledge, which was from 85.3% to 76.7%. This is partly due to the discovery that REA-LP alone will not make students understand the subject, requiring dedication on their part, in addition to intensive practice, for an effective learning of algorithms and LP. During the interviews, most participants thought they had gained knowledge thanks to the tool, which helped them to learn more and efficiently.

Good performance is one of the ways to positively evaluate an educational environment, according to the Constructivism Learning Theory.

Regarding the reaction and acceptance of the REA-LP, most students pointed out that the tool is relevant, adequate to the content of the discipline and that it facilitated the understanding of its content, presenting, according to the students, good explanation, organization, and being easy to understand. In addition, most students stated that the visual resources presented by the tool were ‘excellent,’ positively citing the color patterns, multimedia resources, ease of locating the material and the mobile experience.

Regarding the types of media in the REA-LP, there was a tie between ‘text’ and ‘dynamic image,’ with one-third of the students stating that they were the most used, followed by ‘video.’ The ‘text’ was preferred due to presenting the content in a more summarized and objective way; ‘dynamic image’ was chosen because it facilitates the visualization of the step-by-step examples. The review modules present in the REA-LP, one of its differentials in relation to other OERs and similar tools, were well received by the students, with most agreeing that they helped them to effectively review the contents in the discipline, even in other subjects.

As to issues related to MMLT, most students pointed out that the tool complies with its principles (modality, signaling, contiguity, segmentation, anticipation, coherence, and redundancy), and that their visual and/or verbal working memories were equally stimulated, facilitating learning. In addition, most students did not feel overwhelmed by the information presented by the media, pointing out that the participants’ working memories, visual and/or verbal, were not overloaded. They claimed to choose the type of media that best suited their preferences and learning style.

Most students agreed that the textual information in the REA-LP presented hints or signs of what should be observed in the images, indicating compliance with the MMLT signaling principle, making learning more efficient; the students reported that the texts complement and describe the images, thus facilitating their understanding.

Regarding the principle of MMLT contiguity, most students thought that the textual information and the corresponding images are presented next to each other and, according to the participants, it allowed verifying the content in practice, right after reading about it, facilitating learning.

Most students expressed that the dynamic/segmented images (GIFs) in the REA-LP facilitated the learning of the subject, being in accordance with the principle of segmentation of MMLT, thus favoring their learning. Dynamic images are always cited by students as one of the tool strengths, making classes and studies more interesting by presenting the content gradually. Also, most of the students stated that the way in which the contents present in the REA-LP are presented and, later, detailed, was adequate. Based on the MMLT principle of anticipation, learning occurs more easily when this happens. The students mentioned that this way of presenting the content helped those who have difficulties in the discipline, making the tool and the content more easily understandable.

According to the participants, the tool complies with the MMLT coherence principle, making them learn better, as most disagreed that the tool presents words, sounds, or images that are irrelevant to learning, citing that the present resources are relevant to the discipline and that helped them to learn more.

Regarding the principle of MMLT redundancy, most students thought that the tool does not have words, sounds, or images with excessive repetition of information. If there were, excessive repetition could cause cognitive overload, hindering learning. The students deemed that the contents presented are well distributed and detailed, and that the repetition of information in different media is beneficial.

Regarding the devices students used to access the tool, there was a tie between smartphone and desktop, followed by notebook. The preferences for these devices, according to the reports obtained from the questionnaires and interviews, are due to their availability, the ease of using the smartphone for consultations and the larger display of the desktop computer, which once again indicates the importance of developing educational tools with responsive design as a primary guideline.

Regarding the participants using the REA-LP again in future activities, the majority (83.3%) said yes, indicating an increase in relation to the expectation, which was 41.2%. The main reasons for this were to review and to clarify doubts about the content of the course. Most students agreed that other disciplines should explore tools similar to REA-LP for the study and reinforcement of the contents studied in the classroom; the main reasons given were the source of direct research to the subject, possibility of revision, increase of motivation and interest in the subjects, and assistance to difficulties in the subjects.

Finally, participants were able to express general comments about the use of the REA-LP, indicate possible defects and/or suggest improvements. Overall, the reaction and acceptance were positive, with students enjoying using the tool inside and outside the classroom for studies and content review. In addition, the participants pointed out that they were able to practice with the extra activities, learning more about the content. Still in this aspect, they also reported not having found defects, and took the opportunity to express that the use of the tool should be extended to future classes.

The performance test (post-test) had the participation of 30 students who used the REA-LP during classes. The test consisted of theoretical and practical activities related to the content of the discipline present in the tool and had a maximum value of 10 points. The general average obtained by the students in the activity was 7.9 points, and 56.6% of the students obtained the maximum grade, which allowed observing that most of the students obtained excellent performance in the referred test. It was also verified that the students that responded positively to the questionnaires reached a higher average in the performance test, and it can be concluded that the good reaction to the use and acceptance of the tool by the participants may have contributed to their better performance.

4.1. *Correlations*

When applying Pearson's Correlation between the questions of the questionnaire of reaction to the use and acceptance of the tool, 13 occurrences with coefficient r greater than 0.6 were found. Due to the restricted number of participants, this coefficient value can be considered as a strong correlation. As can be seen in Fig. 5, there were no occurrences with negative r coefficients lower than -0.5, thus not having significant negative correlations.

Questions	Q3	Q4	Q5	Q7	Q8	Q9	Q10	Q11	Q12	Q13A	Q13B	Q13C	Q14	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q27	Q28
Q3	1.00																							
Q4	0.46	1.00																						
Q5	0.40	0.70	1.00																					
Q7	0.21	0.05	0.32	1.00																				
Q8	0.20	0.36	0.64	0.11	1.00																			
Q9	0.33	0.70	0.26	-0.17	0.25	1.00																		
Q10	-0.02	0.29	0.38	0.49	0.35	0.18	1.00																	
Q11	0.62	0.35	0.43	0.54	0.33	0.15	0.44	1.00																
Q12	0.71	0.64	0.47	0.18	0.28	0.68	0.13	0.40	1.00															
Q13A	-0.19	0.22	0.57	0.22	0.52	0.03	0.15	0.10	0.13	1.00														
Q13B	0.21	0.30	0.21	0.17	0.30	0.39	0.12	0.15	0.48	0.35	1.00													
Q13C	0.08	0.54	0.44	-0.05	0.27	0.49	0.36	-0.03	0.33	0.22	0.52	1.00												
Q14	0.16	-0.19	-0.06	-0.05	0.07	-0.05	-0.20	0.07	0.04	0.05	0.34	0.00	1.00											
Q17	0.30	0.27	0.45	0.43	0.35	0.25	0.04	0.22	0.32	0.39	0.22	0.04	0.11	1.00										
Q18	0.44	0.28	0.11	0.03	-0.05	0.39	-0.09	0.20	0.49	-0.03	0.31	0.06	0.29	0.00	1.00									
Q19	-0.24	-0.18	-0.10	-0.08	-0.15	-0.30	0.04	-0.16	-0.33	-0.28	-0.40	-0.22	-0.43	-0.16	-0.31	1.00								
Q20	0.41	0.49	0.64	0.57	0.29	0.21	0.39	0.56	0.35	0.33	0.28	0.17	0.18	0.57	0.19	-0.26	1.00							
Q21	0.15	0.04	0.02	0.35	-0.07	0.02	0.12	0.30	0.09	-0.14	0.13	-0.09	-0.12	0.19	-0.02	0.13	0.16	1.00						
Q22	0.19	0.17	0.29	0.27	0.11	0.12	0.11	-0.03	0.26	0.00	-0.03	0.23	-0.20	0.50	-0.07	-0.06	0.25	0.12	1.00					
Q23	0.69	0.60	0.51	0.41	0.18	0.46	0.19	0.54	0.87	0.20	0.40	0.18	0.09	0.35	0.42	-0.37	0.58	0.16	0.25	1.00				
Q24	-0.11	-0.40	-0.09	-0.09	-0.01	-0.48	-0.03	-0.05	-0.34	-0.10	-0.26	-0.39	-0.19	-0.12	-0.04	0.47	-0.14	0.11	-0.08	-0.43	1.00			
Q25	-0.23	-0.32	-0.03	0.10	-0.04	-0.44	0.17	-0.12	-0.40	-0.08	-0.41	-0.25	-0.28	0.06	-0.31	0.53	-0.09	0.21	0.23	-0.42	0.60	1.00		
Q27	0.45	0.29	0.53	0.59	0.35	0.00	0.53	0.51	0.35	0.09	0.06	0.06	0.16	0.24	0.11	-0.14	0.60	-0.02	0.20	0.47	0.00	0.05	1.00	
Q28	0.29	0.16	0.10	0.20	-0.18	0.08	-0.24	0.10	0.30	-0.01	0.08	-0.14	0.02	0.30	0.07	-0.02	0.35	0.05	0.19	0.41	-0.08	-0.12	0.15	1.00

Fig. 5. Correlation between the questions of the questionnaire of reaction to the use and acceptance of the tool. Source: The authors.

The first three correlations observed are between question Q3 and questions Q11, Q12 and Q23, indicating that the fact that students liked the idea of being able to access an OER at any time, when necessary and at no cost, directly influenced the ability to use the knowledge acquired in future practices, in increasing the level of knowledge in relation to the discipline, and also in the judgment that the way in which the contents present in the REA-LP are presented and, subsequently, detailed, is adequate.

An educational resource that presents its content properly, following the MMLT anticipation principle, and that is available for students to access showed to positively impact the increase in student knowledge level.

Another four correlations are observed between question Q4 and questions Q5, Q9, Q12 and Q23, indicating that REA-LP being understandable and easy to handle is positively correlated with the fact that it presents the necessary resources for the adequate study of algorithms and programming logic, with the activities being appropriate; the use of REA-LP has facilitated student understanding of the content of the discipline, with the increase of their level of knowledge related to the subject, and also with the appropriate way in which the contents are presented and, later, detailed. It was thus possible to verify that an easy-to-use OER, which presents the necessary content and in an uncomplicated way for the proper study of the discipline, following the MMLT principle of anticipation, as well as appropriate activities, have a positive impact on increasing the level of knowledge of the students who use it.

REA-LP presents the necessary resources for the adequate study of algorithms and programming logic (Q5) is positively correlated to the fact that the textual information present in the REA-LP presents hints or signs of what should be observed in the images (Q20), directly influencing the interest of students in relation to the discipline classes (Q8). It can hence be observed that an OER that presents the necessary resources for an effective study of the discipline; the principle of MMLT signaling has a positive impact in terms of increasing the interest of students in the classes.

Regarding the resource to present appropriate activities and its use to facilitate the understanding of the content of algorithms and programming logic (Q9), this fact is positively linked to the increase in the level of knowledge of the participants in the discipline (Q12). The increase in the level of knowledge is also strongly correlated with the principle of MMLT anticipation: the way in which the contents in the REA-LP are presented and later detailed (Q23).

Since the textual information in the REA-LP presents hints or signs of what should be observed in the images (Q20), it is positively correlated with the students wanting to use the tool again (Q27), indicating that the MMLT signaling principle can present a positive effect on student willingness to return to exploring the tool.

Finally, the finding that the tool does not present words, sounds, or images that are irrelevant for learning the concepts of algorithms and programming logic (Q24) is positively correlated with its not presenting words, sounds or images with excessive repetitions of information (Q25), pointing out a correlation between the principles of coherence and redundancy of MMLT for this study.

5. Final Considerations

The main motivation of this research is that the learning of algorithms and LP is one of the greatest challenges to students of computer courses and similar ones, at the technical and higher level, several being the difficulties faced, namely: the use of professional programming languages presented in a foreign language, the use of inadequate and/or outdated teaching models, the need for logical-mathematical and problem-solving knowledge and behavioral problems, such as lack of motivation, engagement, time management and trust are also highlighted. These difficulties are more evident in high school students, who study in a teaching model that does not encourage the development of the necessary skills and does not consider the peculiarities of each student.

Thus, seeking to alleviate the difficulties by learners, this research presented the educational tool REA-LP, an open educational resource aimed at the study of algorithms and programming logic at a technical level, allowing their use and practice, without restrictions of location and time, being available in an open and free way. The tool allows students to choose the learning objects that best meet their preferences and educational needs, thus contributing to the modernization of the traditional teaching model, helping to improve the quality of education. Furthermore, the tool presents its content with an easy-to-understand pseudo-language, using VisuAlg, a tool developed for academic environments, which has various didactic characteristics, a simple syntax and is in Portuguese language, thus eliminating the language barrier and allowing the focus on the development of algorithmic thinking.

One of the REA-LP differentials are the presence of fundamental mathematics and introductory logic modules, essential subjects for understanding and developing algorithms. The review modules were well received by participants, who justified it by saying: "*They helped a lot to review things that I had already forgotten*"; "*Wow, and how! The difficulty I had with them has improved a lot*"; "*Yes, they helped me not only in this subject of the course, but also in other subjects.*"

When comparing the results obtained with those of the related OER, presented in Section 2.5, which underwent studies and evaluations, a similarity in their findings can be observed, with the OER being well received by the participants and facilitating learning. It is also important to highlight the lack of tests, case studies and validations of the related tools found during the study, as well as the absence of the use of learning theories in their development and validation, and also to point out a lack of works directed to secondary and technical education.

In general, the reaction and acceptance of the REA-LP were positive, surpassing the expectations of students who enjoyed using the tool inside and outside the classroom, for studies and content review, with reports such as: "*The way the site was planned makes me want to delve deeper into the subject, watching video classes or reading texts on the subject*"; "*It became something more dynamic and interactive, which fits our internet generation*"; "*When I wasn't in classes and I didn't have the teachers to help me, I had to resort to the REA-LP, which helped me a lot.*" This increased their level of knowledge, motivation, and interest in the discipline, allowing students to practice with extra activities, in addition to choosing the type of media that best suits their preference and learning style. Furthermore, the tool proposed allowed complying with the use of new technologies in education and adaptation to the current profile of students in informatics courses, who are usually more connected and technologically engaged, and the adequacy of the traditional teaching system that does not consider their heterogeneity.

For future works, we suggest creating a cycle of evaluation and improvement of the quality of the REA-LP content. Students can thus be encouraged to create new LOs, reinforcing their active learning. Efforts should also be invested in using the REA-LP, as well as the dissemination and sharing of the tool so that other schools that have technical education in informatics, as well as the community in general, can take advantage of the OER developed. Aiming at specifically evaluating the possible performance gain provided by REA-LP, we suggest carrying out experimental research with the presence of a control group, aiming to quantitatively determine if its use can promote a significant increase in the performance of students, and, if possible, it can be more effective as compared to traditional classes. Finally, an accessibility and usability assessment of the resource can be carried out, promoting the use of inclusive design.

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