An Automated Environment for Teaching Programming Logic on Distance Learning IT Courses

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Abstract: Disciplines devoted to teaching programming are present in all courses in the area of information technology and traditionally they are part of the basic structure of these courses. For this reason the discipline of programming logic has been the gateway for information technology students. These disciplines have presented a high rate of students failures because it requires the students to have a high level of abstraction associated with systematized reasoning. The main objective of this article is to present an interactive environment that is seamlessly inserted in a e-course didactic material in order to expand the offer of effective learning automated mediators. This feature turns the teaching material into an interactive tool, which is more attractive to students and likely to help them in succeeding in these programming courses.

1 INTRODUCTION

The discipline of programming logic, traditionally, has been the gateway for students in the area of information technology. This discipline requires the students to have a high level of abstraction associated with systematized reasoning, which together, form the necessary cognition needed for describing actions in a step by step manner in order to construct programs that will generate the desired results. This is the main reason for high failure rate in the discipline of programming logic.

Since 2012, the Metropole Digital Institute of the Federal University of Rio Grande do Norte has been developing a technical distance learning program (in the semipresencial mode) in the area of information technology. The discipline of Programming Logic is part of the common core of this program and, over the last six years, a collection of didactic material has been developed to offer support to the approximately 1,680 students who ingress each year in this course.

The main objective of this work is to present a technological resource that we developed, an programming environment which we integrated to the current model of the didactic material of the discipline Programming Logic of the course. This new feature effectively expanded the offer of learning mediators and, as a consequence, fosters an increment in the current success rates in this discipline. Such a change, in addition, turns the teaching material into a more attractive one to students. This intervention was developed as a result of a master's degree research, in which descriptive frequency analysis was performed on quantitative data about the academic performance of 2,500 students from the first semesters of the years 2015 and 2016. In addition to questionnaires with more than 600 students for identifying the socio-pedagogical profile of these students.

In the analysis of the academic scores of the students sample, from which the students who droped the course were removed, a correlation of approximately $R = 0.96$ was verified between the final (semester) average of the student with the discipline of Programming Logic, that is, students with the high average in this subject presented higher results in the set of subjects of the semester. This result made it clear the importance of this discipline to the students' overall performance in the course.

In the applied questionnaires it was also verified that the majority of the students have a computer and easy access to the Internet in their residences. In addition, it has been detected that the students are constantly consuming informational and instructional content from Internet sources.

As a result of our initial researches, an intervention proposal was implemented and inserted in the

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didactic material used in the discipline of Programming Logic of the referred course. The functionalities were elicited from the data obtained in the applied questionnaires and from the analysis of platforms and environments for the teaching of programming that were indicated by the students, such as Codecademy and Khan Academy. The research team experience as course mediators and teachers was also a source of inspiration for the environment requirements.

The resource was developed and integrated in the didactic material that allows the student in programming exercises, using a high level programming language that uses commands written in their mother language and submit their answers as "programs" that are evaluated through an automated process.

By including an automated evaluation process integrated with the didactic material of our technical courses, our development turned this material into a interactive and more attractive one. This interactivity includes automated correction of algorithms and a full access to evaluation results to the students, who will be more effective in deciding its learning timing.

2 BACKGROUND

E-learning refers only to teaching modalities whose learning is not linked to the physical presence of the students, and the didactic content is made available through various communication vehicles, such as the postal and broadcasting system, and television. Some authors (Piva-Junior et al., 2011) argue that one of the great problems of this modality is the difficulty of students to interact in the learning process. This limits the exchange of experiences between them, as well as the difficulty of solving doubts with teachers or other colleagues because of the limitations of one-way communication of the first mass media.

Used successfully in on-line education processes, virtual learning environments that provide activities with automatic correction and feedback are often used. The elaboration of well-structured tasks can lead the student to make questions and consequently discoveries, promoting the students' conduction to deeper levels of learning. The automatic feedback offers the students a quick access to the expected response for the exercises he answered and allows a better planning of his evolution in the course.

The contents are presented through the didactic material, that is the instrument that should guarantee the "dialogue" between the teacher and the student (Preti, 2009). Thus, there is a clear and ultimate need for this material to be as interesting and attractive as possible, becoming a positive mediator between teaching and learning.

The E-learning class should aim for activity-centered learning and interactivity that encourage knowledge building and problem-solving (Preti, 2009). The construction of teaching tools that aid programming teaching should have clear and precise learning objectives, with a language whose form and meaning are clear and contextualized, associated with a well-articulated information architecture.

In (Belloni, 2003), the author argues that the main characteristic of the Digital Information and Communication Technologies (DICT) is the interactivity, technical characteristic that means the possibility of the user interacting with a machine. In this sense, interaction refers to the action between subjects, mediated or not by a technology.

It is noteworthy that in E-learning, the teacher does not go along with the class. Therefore, he is unable to explain again and to look at the student and realize that he did not understand the subject. This aspect of teaching ratifies even more the importance of having the maximum possible interaction between the student and the didactic material made available.

This emphasizes the relevance of didactic material in E-learning, because in face-to-face teaching the materials complement the direct action of the teacher. In E-learning, the integration and complementarity of the materials used to establish the effectiveness of the student's link with knowledge. However, as a matter of fact, the teaching material does not replace the teacher (Possolli and de Quadros Cury, 2009).

In (Possolli and de Quadros Cury, 2009), the authors list four main characteristics that can be identified as essential for E-learning materials. Essentially, such material should be interactive, dialogic, multimedia and they should stimulate learner autonomy. In this way, it is verified that the E-learning didactic material must maintain a contextualization with the content, stimulate the action and the thought of the learner so that it can construct meanings in its learning process, besides fomenting the search for autonomy.

3 THE CONTEXT OF COURSE

The technical courses offered by the Metropole Digital Institute are structured in 4 modules: Basic, Intermediate, Advanced and Integrator. All incoming students must take the basic module, common to all emphases. At the end of the basic module, the students who succeed must chose one of the available emphases: Industrial Automation, Electronics, Internet Programming, Programming of Digital Games and Computer Networks.

The Basic Module has a total workload of 280 hours and it is distributed in 6 subjects (Table 1).

Table 1: Subjects of the Basic Module of the Technical Courses of the Department Name.

Subjects	Subject Load
Introduction to Information Technologies	60h
Technical English I	40h
Applied Mathematics	40h
Computer Architectures	20h
Programming Logic	60h
Operacional Systems	60h

The student approved in the basic module defines, at the beginning of the next semester, the emphasis in which he wishes to proceed. From this point, the student has contact with more specific subjects in the chosen area. In the intermediate module, there are subjects in common between two or more emphases.

Upon successful completion of the intermediate module, the student proceeds to the advanced module of the area selected in the previous semester. In this module, the amount of common subjects between the emphases decreases, and the content is more specific in each emphasis, offering an opportunity for the student to deepen his knowledge in the chosen area.

Students have face-to-face (on-campus) and virtual meetings with a mediator on a weekly basis. The classes are composed of 40 students at most, with a mediator that supervises the development of the activities in both on-campus and virtual meetings. The activities of this mediator in the weekly meetings are: to provide support for the student with the resolution of exercises and to answer questions about the week subjects in the virtual environment.

3.1 The Didactic Material Technologic Structure

Our didactic materials are made available to the Technical Courses students through an on-line platform, which uses the same technologies adopted in modern applications for the web: In the front end uses HTML5[1], CSS[2] with materialized CSS[3] and JavaScript allied with jQuery[4]. In the back-end we use PHP and a PostgreSQL database.

In spite of this "technological power", the educational resources employed are limited to that of a book in digital format by allowing content to be viewed through various types of devices, including mobile devices.

Focusing on the contents of the teaching material of Programming Logic, we observed that they are composed of three items: text, images and short videos. The contents are predominantly arranged through texts with images and are complemented with videos in most classes. These videos began to be produced and inserted in the teaching materials from the first semester of 2014, as a first proposal to make the presentation of the contents more dynamic and to initiate with the use of computational resources to produce richer materials.

This analysis allowed us to conclude that the didactic material of the Programming Logic discipline was predominantly static, despite the presence of the videos, since it does not allow interactivity. According to (Silva, 2001), interactivity allows students to go beyond the condition of passive spectator to the condition of operative subject, understood as an exchange of actions, control over events and modification of contents, which does not occur with the didactic material we analyzed.

4 THE AUTOMATED ENVIRONMENT

The resource developed is a group of technologies to create an environment with a code editor in which the student can write his algorithms in response to exercises proposed in the the didactic material. This environment was constructed to improve the experience of the student of e-learning courses and to expand the learning mediators, more specifically for Programming Logic.

In the application of the questionnaires the students were asked if they knew any interactive platform for teaching programming. The majority (37% of the 207 participants) mentioned the Codecademy platform; the second most indicated platform was the Khan Academy, which obtained a percentage of 19% of the answers.

From this point of view, an evaluation was made of the learning mediators used by these platforms for the context of Programming Logic. In general, both require an autonomous learning. It is important to emphasize that within the context of the e-learning, the student dictates the own pace of learning, according to his performance in conducting his studies. Autonomous learning happens when the student has the initiative, regardless of an academic need, seeking to obtain certain knowledge.

[1]HyperText Markup Language version 5.
[2]Cascading Style Sheets.
[3]Framework CSS that implements Material Design.
[4]JavaScript Library.

It is known that one of the premises for learning and developing programming skills is a constant practice. The two platforms mentioned by the students seek to teach this knowledge through the use of examples and exercises.

In general, these platforms have characteristics of tutorial or exercise-and-practice software (Valente, 2008). Such platforms need a student interaction with the tools. There is, hence, a clear need for interaction on the part of the student that should provide answers to proposed activities and should, as a consequence, receive feedback from the platform.

It is important to notice that interactivity is the main premise of these platforms, Codecademy and Khan Academy. According to (Fardo, 2013), through interactive platforms, they also seek to create an immersion environment with the purpose of motivating individuals to act, assisting in problem-solving and promoting learning. Thus, the resource that is presented in this paper opens the possibility, in the context of the discipline of Programming Logic, of the students to carry out their exercises with interactivity within the didactic material.

The use of tools that allow interaction has been demonstrated to have positive results. A study presented in (Lee and Ko, 2015), demonstrated an improvement of up to 40% in the success rate of programming courses with interactive tools such as Codecademy.

Through the strategy of interactivity of platforms, the level of action and reaction increases, leading to small challenges or tasks that, when completed, give the student a score and a feedback on the activity performed. This scoring strategy is adopted by most of the platforms, as well as in those evaluated and developed in this work. It leads to a greater involvement of the student with the platform. As a consequence, the student will, seamlessly, perform a greater amount of tasks (Fardo, 2013).

In our work, we used tools that could be integrated with the technologies used in the teaching material platform. In addition to the technical requirements for integration and coupling, licensing matters were also taken into account. We, therefore, defined that the resources of third parties that were to be integrated in our proposal should be open source. This requirement was also a consequence of a clear need for customization which could arise during integration with the teaching materials technologies.

The teaching materials used are made available through a web platform with technologies that are used in the development of web sites or systems. The use of these technologies removes the need for any software installation: only a compatible web browser is needed.

4.1 Used Technologies

The teaching materials was initially produced for the technical courses and are maintained by the Multimedia Production Sector (MPS) of the Metropole Digital Institute. The first step in our work was to adapt the existing technological structure, presented in Table 2.

Table 2: Initial Technology Architecture.

Technology
Cloud Server with Linux Operating System
Apache application as HTTP server
PHP programming language
Framework JavaScript jQuery
Framework CSS Materialize
PostgreSQL Database

These technologies established some of the non-functional requirements, such as the use of the PHP programming language, PostgreSQL DBMS, in addition to the frameworks Materialize CSS and jQuery.

The Khan Academy and Codecademy platforms, indicated by the students in the application of the questionnaires, were considered in this study. The structures of these platforms have been evaluated in interface aspects, existing functionalities, and student interaction features. Both platforms have common characteristics and the main one is the presence of a text field to insert the responses of the activities.

The resources presented in the programming courses were evaluated. Both environments have the text field with features that simulate a source code editor and some other features present in software development IDEs. Among other existing features, we emphasize the presence of syntax highlighting, which is the specific formatting, usually with the use of colors, in the programming languages keywords. This visual feature allows the student to detect when a language command in their work was not correctly spelled. It also allows visual aid in the identification of variables and data.

Thus, one of the mandatory requirements detected from the analyses performed on the Khan Academy and Codecademy platforms was the need for a code editor with syntax highlighting, which would necessarily work from a web browser.

Faced with this requirement, we searched for an open source text editor for web pages. Our research lead us to CodeMirror (CodeMirror, 2017), an open source text editor implemented in JavaScript, which mets the requirements already mentioned. Its main functionality is to allow the editing of source codes

within a web page and natively has several language modes. It also allows the addition of new functionalities through extension modules (plugins).

The official documentation of CodeMirror was studied, followed by tests of integration of the component with the didactic material of the Technical Courses targeted for this work. After the coding process, it was possible to succeed in the integration test. Since this feature met the initial requirements, CodeMirror was adopted as our web code editor.

4.1.1 The Potigol Language

With the definition of the tool to be used for writing codes, the next step of the research consisted in the definition of the programming language that should be used in the interaction between the student and the proposed exercises.

In our case, the discipline of Programming Logic is projected to develop a structured reasoning to develop computing solutions to small problems. The discipline used a tool called (VisuAlg, 2016). This software runs only under the Windows operating system and therefore does not meet the needs of a cross-platform application.

Although its license is free for use and distribution, it is not open source, what makes it extremely difficult to customize to meet specific needs. In the case of this work, one of our requirements is to make the tool available to online (hence, multiplatform) execution. Therefore, no feasible solution was found to integrate it into our didactic material of the discipline of Programming Logic. Otherwise, the student would needed to download VisuAlg in order to develop and test the exercises.

The fact that you do not need to install any software to perform the exercises allows the student to study the discipline and test their algorithms on any computer connected to the Internet. Consequently, if the student needs to use a 'LAN house' or a third-party computer, he should not face problems during his studies. This is a relevant element since the diversity of places where the student has access to the Internet was observed in the answers to the questionnaires. Therefore, given the limitations of VisuAlg that were presented, we chose not to use it in this research.

This limiting technical factor of VisuAlg reinforced the search for a language that met the requirement of being open source and allowing integration with CodeMirror. A viable option was Potigol, a new multi-paradigm programming language specially designed for beginners, with a Portuguese syntax (Potigol, 2016). The creators of Potigol claim that (Lucena and Lucena, 2016):

> The main objective of introductory programming courses is to enable students to express solutions to problems using a programming language. A programming language for beginners needs to be able to express algorithmic solutions in a natural way. The language must not be an obstacle. So it needs to be expressive and simple with an intuitive syntax. Potigol's syntax is inspired in dynamically-typed languages, which are well known for their simple syntax. Type inference makes statically-typed languages look like dynamically-typed languages. The programmer does not need to explicitly define the type of variables.

The authors (Noschanga et al., 2014) also argue that programming teaching should focus on problem solving skills, learning a programming language as a secondary aspect, and the low fluency of students in the English language can also interfere with the process of learning.

In view of the above, and after initial analysis of the technical characteristics of Potigol, an evaluation was carried out to verify the integration with CodeMirror. This evaluation began with the reading of the official Potigol language documentation.

The next step consisted in the configuration of a local testing environment with all the resources of the current didactic material of the Technical Courses of the Specialized Academic Unit. Then, one of the pages in the Programming Logic material was selected. In the next step, the necessary procedures for the inclusion of CodeMirror were realized.

Next, Potigol was integrated to our environment, with a minimum resource implementation in PHP. After the development of such codes, it was possible to perform the communication between CodeMirror and Potigol through PHP and that was already adopted in the platform of the existing didactic material.

The test environment made it possible to communicate between the CodeMirror and Potigol components by running an algorithm "Hello, world!" on the server. At the end of the execution of the algorithm, the output generated by the test was sent in response to the AJAX request and then presented in the user interface. The successful technical test of integration resulted in the choice of Potigol as the programming language of the enviroment proposed in this study.

4.2 The Interaction Tool

The Figure 1 shows of use cases that were elicited. The features that are highlighted in the Use Case Diagram were implemented in the current version of the tool: (i) Do Exercise; (ii) See execution feedback; (iii)

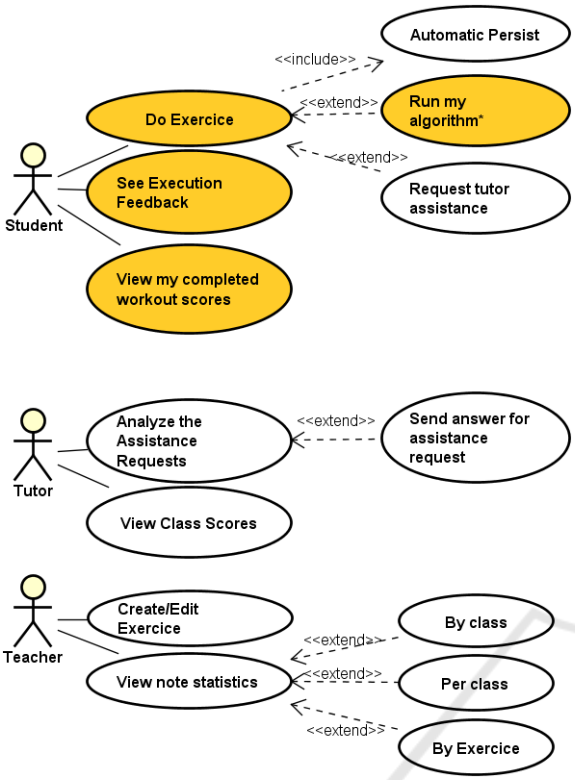

Figure 1: Use Cases Diagram.

See my completed workout scores; and (iv) Run my algorithm, the user case considered of the greater risk was marked with *, which was successfully achieved

4.3 The Tool's Architecture

The implemented architecture uses Asynchronous Javascript and XML communication were used. This feature aims to prevent the page loaded in the student's browser from undergoing a new loading process. All communication required for the "Test My Algorithm" use cases, responsible for the feedback feature, and "View my completed exercise notes", made use of AJAX communication to maintain an unfilled page experience.

The student, when using the tool proposed in this work, only needs to write their algorithm and to push the feedback button. This starts the process of verifying his response. First, the tool sends the student's algorithm to the web server. This communication occurs through an asynchronous AJAX request and post type[5] type.

When the server receives the request, it checks whether the user is authenticated and has permissions to execute the method that will trigger the procedure to construct the response to the user. Then, the information sent by the user is retrieved: (i) class number; (ii) the number of exercise; (iii) and the student's algorithm.

After retrieving this information, to reduce the chances of losing the algorithm sent by the student, the tool first persists the algorithm in the database. Only then, it starts the scoring process.

The next step after the persistence in the DBMS is the writing of the algorithm in the file system of the operating system. This procedure is necessary, so far, to execute the codes in Potigol, since for the execution of the algorithms written in this language we need to save their text files. It is worth noting that these files are saved in a temporary directory and soon after the tests they are removed. The submitted algorithm, though, is stored in the database.

4.4 The Scoring Process

The "scoring" process of the algorithm is performed with the execution of black-box tests. These tests are defined by the teachers, who are responsible for the construction of the questions of these exercises to be applied through the didactic material. In addition to the input data, it is also necessary to provide the output data that must be generated by the correct algorithm.

This process of automatic correction of algorithms is described in (Pelz et al., 2012) as a dynamic approach, situation in which the algorithm is executed a certain number of times with known inputs. If the output values match the expected values the algorithm is considered correct. We use some variations to define a score for the student's algorithm ranging from a completely exact answer to an incorrect answer.

With the use of this dynamic approach of correction of algorithms, it is essential to have test cases for each question. This amount will always be intrinsic to the developed exercise.

In this way, each question proposed in the didactic material must have a specific test bench to be used in the process of correction of the algorithm produced by the student. Each exercise has a different problem and, for this reason, the test bench should be specific to each question.

The student's algorithm is executed once for each test input that have been defined for the question. At each test of the student's algorithm, the system assigns a note according to the similarity to the expected response.

At the end of the test cycle of the question, the average of the exercise is calculated as a simple arith-

[5]One of the request methods performed through the HTTP protocol.

Figure 2: The Tool's Layout.

metic average of the test cases. The mean score is then persisted in the database and presented in the student's grading chart.

Table 3 presents the scores attributed by type of error detected in the evaluation of the outputs generated by the student's algorithm. It is reinforced that the procedure is an aid to the student to obtain feedback quickly, positive or negative, for the exercise performed and in this way can make the decision to ask for help or investigate the result and its algorithm from the feedback generated by the tool.

Table 3: Table of levels score by type error verification.

Differences Level	Score
No differences, the answer is correct	10.0
There are differences only in blank lines	9.5
There are differences only from spaces to plus/minus	9.5
There are only uppercase/lowercase differences	9.0
There are differences between lines and blank spaces	9.0
There are differences between blank lines	8.5
There are differences in spaces, lines, and upper / lower case	7.0
Unfortunately the answer is not correct	0

4.5 The Tool's Interfaces

Figure 2 shows two interfaces (separated by the dotted line) used by the student. In the first interface, in its upper region in the dark color region, the exercise statement is shown in the center and, below it, the CodeMirror text editor. In the same interface, two buttons are presented: "Test My Algorithm" which is responsible for starting the process that will perform the tests in the student algorithm and "View Language Syntax", which opens the page with the documentation simplified syntax of the Potigol language.

Below the buttons, there are three tabs: Result, Generated Output, and My Scores. The first tab is intended for the general feedback of the algorithm. The second one presents the printed output for each student's execution and respective scores.

The last tab lists the notes for the exercises answered by the student and also counts the average grade of each class, calculated from the exercises already answered by the learner. This is the right-hand interface in Figure 2.

The interfaces presented were planned with a focus on simplicity, without harming the presentation of the information. Thus, in these two interfaces, the statement of a proposed exercise and its general feedback and the notes frame that of the exercises performed by the student are present. The interface with the detailing of the feedback for each execution of the exercise is accessed by the option "Output Generated".

The authors (Pelz et al., 2012) defend, from realized experiments, that the feedback provided by automatic correction mechanisms have pedagogical potential. In this way, the presence of feedback can allow the student to reflect on their development and learning and can decide to progress in their studies or review some specific content.

5 CONCLUSIONS

In this paper, we presented an environment with interactivity resources in the didactic materials of the discipline of Programming Logic of the Technical Courses of a teaching institution. This environment allows the students to have autonomy over their studies, obtaining feedback for the programming exercises, which can be executed within the teaching material itself. Considering that the autonomy of the student is one of the pillars of e-learning, didactic materials with dialogic language, multimedia resources and interactivity can be extremely important in the construction of the knowledge of the subject that is learning.

Thus, it is understood that this study considered two pillars placed on the basis of e-learning: interactive didactic material and student autonomy. Given this, it is believed that a didactic material (with dialogic language) enriched with the multimedia resources, associated with the interaction resource with automated feedback allows the students to develop further their autonomy and their programming abilities related to the contents of the discipline of Programming logic.

The inclusion of the resource for dynamic algorithm correction modifies positively contributing to the development of the programming abilities of the new students since they can obtain a faster return to their exercises and thus decide if they should continue to advance in the contents discipline or review other content.

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