RPOIA: A Method of Selecting Learning Objects Using Petri Nets

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Abstract*—This Research Full Paper presents a method to select Learning Objects based on students' cognitive profiles, aiming to facilitate the explained content understanding and programming skills improve. STEM approach has favored the programming skills development in Computer Science courses. Due to initial concepts complexity, many students find it difficult to understand this discipline, causing demotivation or course abandonment. We propose a method using Petri Nets formalism to select a Learning Object that addresses the subject being studied. Petri Nets are formal description techniques used to specify competing systems through graphical and mathematical modeling. Intelligent Agents are computer programs created to automate and perform a certain task or direct interaction with student and propose solutions considered appropriate, based on based on knowledge obtained during the interactions. This research uses the Petri Net to create an Intelligent Agent model, which chooses the Learning Object from answers obtained by applying VAK, an educational questionnaire and results obtained shown to be promising and method was well evaluated by students.

***Keywords*—petri nets, learning objects, intelligent learning objects**

I. INTRODUCTION

Currently days, it is almost unimaginable to work without computer technology. Information technologies used in education received lot of featured in recent times, since they are potential for student's cognitive development, becoming valued allies of educators and object of study of researchers and experts in subject [1]. These instruments, known as Learning Objects (LOs), function as knowledge mediators and can stimulate learning [2], and can work dynamically motivating and stimulating Computational Thinking (CT) in student.

Computational Thinking (CT) dissemination has been commonly employed Programming Logic teaching [3]. Because it is an exact discipline, students cannot assimilate easily and find many difficulties for understanding the concepts and applications, resulting, consequently, in reprobation, locking of the discipline and until course withdrawal [4].

Several Learning Objects (LOs) have already been created and used in Programming Logic teaching, in an attempt to facilitate the discipline learning [2]. However, practices are always applied to class as a whole. Logic should not be taught in a unified way, because students not in same knowledge level, since high school formations are different [5]. In addition, people have different ways of thinking and assimilating knowledge, often related to environment, considering social and cultural contexts where the process goes [6].

Thus, the research question of this paper is: if customize the Programming Logic teaching and employ Learning Objects suitable for students, how much the learning can be improved? Considering the above, we propose a method to select a Learning Object adapted to student's learning profile using Petri Nets to model the Intelligent Agent. We call RPOIA method, of Portuguese expression "*Redes de Petri para Objetos Inteligentes de Aprendizagem*", which in English means Petri Nets for Intelligent Learning Objects. This method seeks to facilitate content assimilation, as it adapts to the different student learning forms. Despite current existents methods, the use of Petri Nets was justified by mathematical model simplicity.

To report the research, this article is structured as follows: Section 2 presents the references that support this work; Section 3 shows the related works and their contributions; Section 4 presents the RPOIA method and its operation; Section 5 describes the method used in this research and Section 6 describes the results and discursions obtained with the research.

II. Background

A. Programming Logic

Logic is an important tool in analysis and presentation of arguments. It investigates whether assumptions imply conclusions, irrespective of their truth or falsity and regardless of their subject matter [7], that is, whether the conclusion is properly justified in view of the available information. Thus, when we refer to Logic, we generally relate to the coherence and use of rational thought.

Often, logic is associated only with mathematics, it does not perceive its application in relation to other sciences. However, computer programming is one of the sciences that stands out on the world stage and uses logic [8]. Programming Logic is defined like as set of techniques to produce coherent and valid solutions, aiming solver computational problems with quality and efficiency.

B. Teaching Programming Logic

One recent trend is the inclusion of Logic Programming teaching in public schools, both for K-12 [9] and for High School students [10]. Programming encourages the logical thinking development, along with planning, problem solving, and teamwork [8]. Logic learning broadens students' perceptions in diverse disciplines such as mathematics, physics, and biology.

However, programming is an art that not all people can easily assimilate. Usually programming logic is one that holds the highest rate of disapprovals and high dropout rates [11]. As process of learning algorithms is something new for beginners programming students, this represents a difficulty and generates resistance, often still fomented by the teacher methodology. Some studies analyze the use of LOs for the teaching of Programming Logic.

C. Learning Objects (LOs)

Learning Objects (LOs) have been causing great impacts on education. Because it is still considered as a recent technology, there is no consensus on the definition of what is a Learning Object. A LO can be defined as "any digital resource that cannot be reused for educational support" [12]. It exemplifies learning supported by computer-based systems, interactive learning environments, collaborative learning environments and others situations.

Learning Objects are materials that can directly interfere with learning and may be video or animation resources [13]. A LO must have a defined educational purpose, an element that stimulates students' reflections and that its application is not restricted to a single context [14].

Even with activities aimed at developing new objects, it is still necessary to improve the developed products. LOs efficiency has been improved by organizations and research groups and have significantly improved to find the ideal tools to solve a specific problem more easily [15]. The LOs have some limitations and with this a new concept emerged, the ILOs, that will be described in the next subsection.

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D. Intelligent Learning Objects (ILOs)

Intelligent Learning Objects use agents to act integrated into LOs, making them smarter objects, which enhances the effectiveness of these instruments. They have same essential characteristics as LOs, but are able to learn and intervene in an environment, flexibly and intelligently, without requiring human intervention.

An ILO is a special type of LO, that is, they are also modular, interoperable, capable of being discovered and reused, considered one most important characteristic of LOs [16]. What distinguishes, according to authors, is that ILOs can generate learning experiences.

ILOs are able to engage in direct interaction with student and propose actions based on the knowledge gained during communication with the learner. Thus, they may find a solution considered appropriate, based on their knowledge, among several different situations. In this work we will show a model the selection of an LO using Petri Nets.

E. Petri Nets

Petri Nets are formal descriptions techniques, developed by German mathematician Carl Petri in 1962, and employed to represent competing systems using graphical and mathematical modeling [17].

It is a promising tool to describe and study information processed by competing, asynchronous, distributed, parallel, non-deterministic or stochastic systems [18]. They are composed of 3 basic elements: **places**, represented by circles, **transitions**, represented by small lines and **arcs**, which serve to connect places to transitions. Fig. 1 shows a Petri Net example.

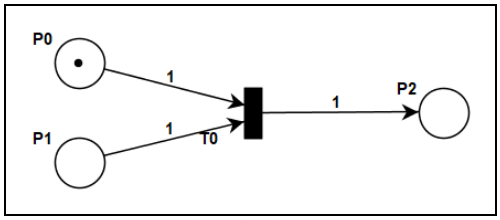

Fig. 1. Petri Net basic components.

A transition is enabled only when all input places are checked. When this occurs, the transition can be performed, that this, the tokens of input places (P0 and P1 in Fig. 1) are removed and placed in output location (P2 of Fig. 1).

III. Related Work

This work was based on research done by Dezani et al. [19], which produced an automatic creation method of interactive narratives for educational digital games, based on the Constructivist theory and using Petri Nets. The model allowed to develop games where a Petri Net analysis is done in real time with each interaction with the user. Games were used to teach Java programming language and, according to authors, the goal was achieved, generating several interactive algorithmic narratives, which are a events system where each

function depends on current state and an input, allowing player to choose actions within game. This individualized experience allowed the player to interact in his own way and in his own time, to assimilate learning.

Research conducted by Peterson [20] also contributed significantly to this work. Authors developed a mathematical model inclusive education process. The inclusive education process was developed with a system with input and output variables and transformation operators of elements. Based on developed diagram, it is possible to design and formalize the functional stages of process, considering the specificities to support technology in inclusive education.

Applying Petri Nets to assist in software development was the work performed by Schmitz et al. [21]. Since creating process, a software is several stages composed, where the next stage depends on previous one, that is, the output depends directly on input, Petri Nets fit perfectly to model the behavior and structure of systems. Authors report that the experiments were successful both because they were able to model the software development processes and because the models created improved the student's orientation in their learning processes.

Based on the related works, we realize the great Petri Nets potential for educational models building, such as for creation of educational games, in stages formalization of an inclusive education technology support process or to improve the orientation in processes software development. This potential was explored to develop a method for selecting Learning Objects, which will be addressed in next section.

IV. RPOIA METHOD

Proposed solution development was motivated by a study to analyze the Programming Logic personalized teaching, aiming to reduce the learning difficulties of discipline contents. Based on related work, we have noticed characteristic that Petri Nets have in making complex decisions reliably. In this way, we propose RPOIA, a method for selecting Learning Objects, using Petri Nets to model an Intelligent Agent. The method consists of the steps described below:

- Collect cognitive Information about students through questionnaires applications.
- Assemble the cognitive learning profile based on Information provided, using Petri Net elements.
- To suggest a Learning Object most suited to student profile.

These steps are represented in Fig. 2, in RPOIA Method Architecture.

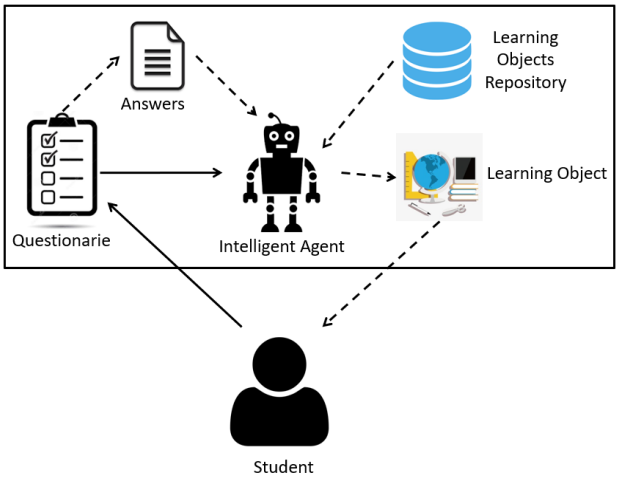

Fig. 2. RPOIA Method Architecture.

In order to build the student's learning cognitive profile, we use learning styles concepts addressed by Saldanha et al. [22], which highlight the VAK's Method use Method (Visual, Auditive and Kinesthetic) because it is based on senses and, according to authors, "responds efficiently the expectations and school demands". According to presented method, the majority of students have a preferred or preponderant learning style to assimilate the various contents presented in classroom. Definitions are set forth in Table I.

TABLE I. LEARNING STYLES AND THEIR FEATURES PRESENTED BY [22]

Learning Style	Features
Visual	Ability to know, interpret and differentiate stimuli visually received. Relationships are established between image and concepts.
Auditive	Abilities to know, interpret and differentiate stimuli received by spoken word, sounds and noises.
Kinesthetic	Ability to organize ideas, concepts and abstractions through stimuli received by body movement.

Above authors propose a questionnaire to obtain additional information to define the student's learning style. To find out what the dominant style is, just add the answers for each letter. Table II shows the questions and answer options for VAK method.

TABLE II. QUESTIONS AND OPTIONS PROPOSED IN VAK METHOD.

1. I would like to be doing this exercise: a) writing b) orally c) performing tasks	2. I like receiving gifts that are: a) pretty b) sonorous c) useful
3. I am easier to remember in people: a) physiognomy b) the voice c) the gestures	4. I learn more easily: a) reading b) listening c) making
5. The activities that motivate me the most: a) photography, painting b) music, lecture c) sculpture, dance	6. Most of the time, I prefer: a) observe b) hear c) do

7. Remembering a movie comes to mind: a) the scenes b) the dialogues c) the sensations	8. On vacations, I like more of: a) know new places b) rest c) participate in activities
9. What I value most in people is: a) the appearance b) what they say c) what they do	10. I realize that someone likes me: a) by the way of looking at me b) by the way of speaking c) for their attitudes
11. My favorite car has mainly to be: a) pretty b) silent c) comfortable	12. When I'm going to buy something, I'm looking for: a) look at the product well b) listen to the seller c) to experiment
13. I make decisions based primarily on: a) in I can to see b) in what I hear c) in I can to feel	14. In excess, what bothers me most is: a) clarity b) noise c) grouping
15. What I like best in a restaurant: a) the environment b) the conversation c) the food	16. In a show, I value more a) the illumination b) the music c) the interpretation
17. While waiting for someone, I stay: a) observing the environment b) listening the conversations c) walking, shaking hands	18. I get more excited when: a) show me b) they talk to me c) invite me to participate
19. when consoling someone, I do: a) show a path b) speak a word of comfort c) hug the person	20. What gives me the most pleasure: a) go to the cinema b) attend a lecture c) play sports

For each proposed question, three options are presented as response alternatives. When choosing a response, an Arc links the Transition to a pre-set Place, where it will add a point to that Place. Based on the VAK Method, the amount of at least 7 points enables the Transition to choose the Place where the selected Learning Object is located. According the cognitive profile, the objects can be a video or a hypertext (visual), an audio (auditive) or an educational game (kinesthetic).

To facilitate the RPOIA method visualization, we will show a simplified model with 3 out of 20 questions of VAK's method. The developed intelligent agent model using Petri Nets is shown in Fig. 3.

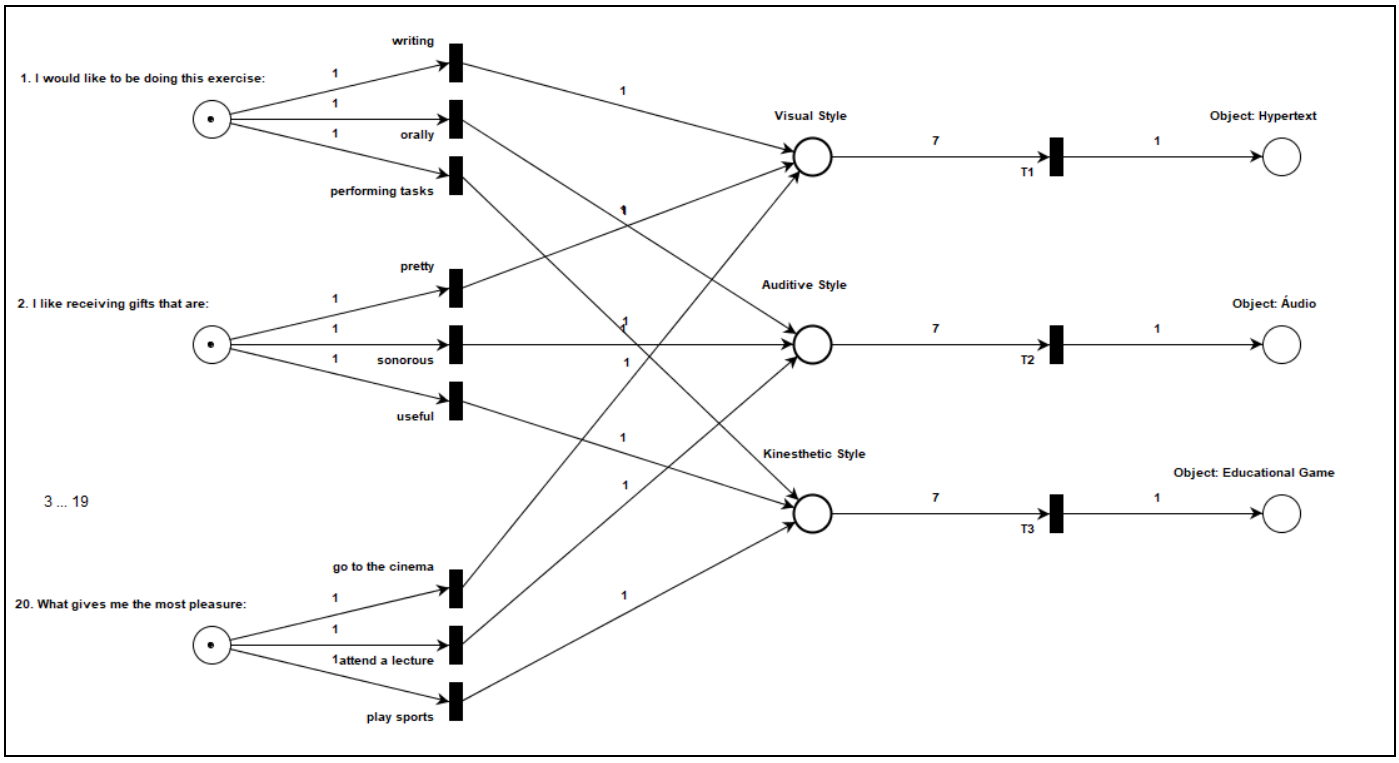

Fig. 3. Simplified RPOIA Method develop by Petri Nets.

V. Research Methodology

To verify the RPOIA method, a practical application was applied at Federal Institute of Amazonas, at Maués, Brazil. The idea was to do an experimental test to collect information about the method's functionality, its flaws and successes, aiming to improve the process efficiency. High school configuration in the selected school aims at the technical and professional learning of students. Classes take place full-time, from 7 am to 5 pm, Monday to Friday. Research was carried out in March 2019 and involved a group of 40 students in 1st year of High School of Federal Institute of Amazonas. The class consists of 20 men and 20 women, with an average age of 15 years. The discipline tested was Programming Logic with the programmatic content of Sequential Structure.

An initial questionnaire was elaborated in Google Forms tool, to obtain information about the class and soon afterwards, the 20 questions that composed the VAC Method were directed, in order to build the students' cognitive profile.

After the students answered the questions, profile was detected using the RPOIA model. Then have been suggested, hypertexts, audios or educational games, according to dominant learning profile detected, on the determined subject.

When students completed the learning objects use, a second questionnaire was applied to evaluate the research and objects used. The discipline teacher also participated in the process, following up and evaluating the method.

VI. Results and Discussions

A. Initial Questionnaire

Before applying the VAK Method questions, some questions were asked to get to know the participants and to analyze interest and their opinions about the relevance of the programming. The results are shown in Table III.

TABLE III. Percentage of students responses.

Questions	Options (%)				
	None	***Little***	***Medium***	***Very***	***Enough***
Your interest degree in programming	2.5	2.5	12.5	45	37.5
The relevance of everyday programming	2.5	20	32.5	35	10

We noticed by the table that there is an interest in the students by the computers programming, course main focus, proven by the percentage of Very and Enough to be higher. Concerning the relevance in daily programming, we noticed that there is a certain balance in the students' opinions. Perhaps this is due to fact that they are starting in programming and, due to the initial difficulties, still cannot understand the importance of programming.

B. Cognitive Learning Profile

The dominant learning cognitive profile was calculated through the answers to the 10 questions proposed by VAK Model. Fig. 4 shows the class profile graph.

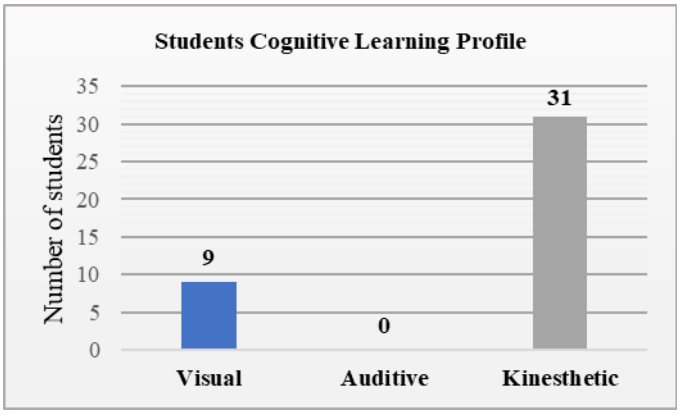

Fig. 4. Students Cognitive Learning Profile calculated using RPOIA Method.

The graph shows that the vast majority of students have kinesthetic profile, indicating that they learn best by performing tasks. By the method, we noticed that no students with the Auditive profile were detected.

In order to compare the result obtained with student's opinion, we used question #04 of VAK Method, where the participant was asked to learn more easily, which could be Reading, Listening or Doing (Visual, Auditory and Kinesthetic). Comparing the student's response with the detected profile, we reached the number of 29 students with the same results and 11 different, that is, the opinion of 72.5% of participants was the same as the result found by the method employed. This result proves the efficacy of the method proposed by this research.

About gender of the 40 participants, we mentioned before, being 20 men and 20 women. Among men, 16 had an answer of informed profile equal to cognitive profile detected by VAK's method, making up to hit of 80%. Among women, method detected 13 profiles with same answer, totaling 65% of hit.

C. Final Questionnaire

The goals of Final Questionnaire were to evaluate the research and the Learning Objects used, together with the participants. Opinions were represented on a scale of 1 to 5, where 1 represented the worst situation, 3 the midpoint and 5 the best situation.

The participants' opinion about Learning Objects employed is described in Fig. 5. We realized that they were well accepted by the students, even though they were their first contact with a digital educational tool.

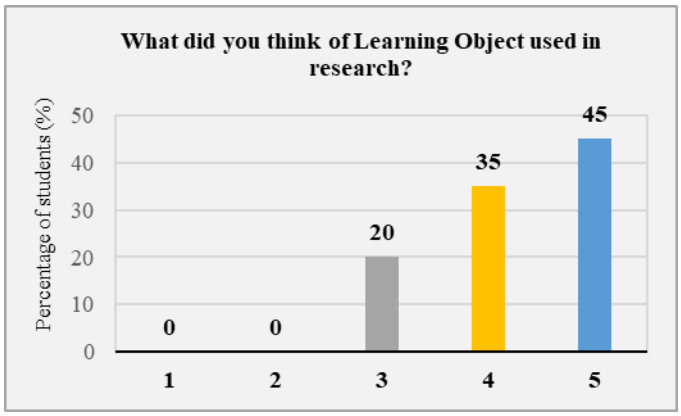

Fig. 5. Students opinion about the Learning Objects employed.

The learning objects employed contribution to improve programming learning was assessed by students. Through the result of graph shown in Fig. 6, we noticed that the majority of students felt that there was a significant contribution to improve the process.

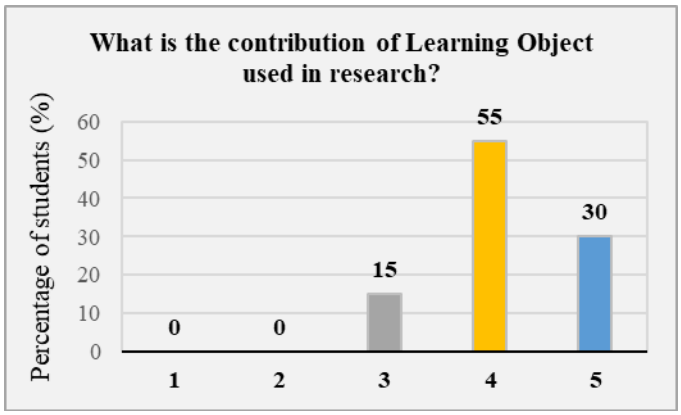

Fig. 6. Students opinion about contribution of objects for learning.

One criterion for a good Learning Object is its ease to use. Participants made this assessment and generally felt that it was easy to use because those who scored the highest and above average together reached 75% of opinions. Result can be seen in Fig. 7.

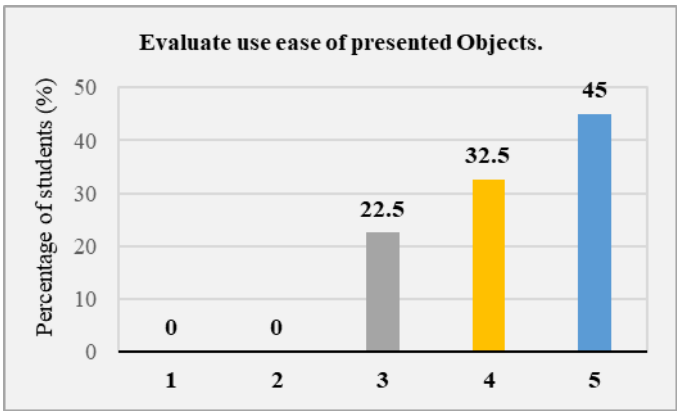

Fig. 7. Graphic about the ease use of LOs.

One important objectives of Learning Objects application in education is to stimulate students' interest in content explained in classroom. In this way, it was questioned how much this research stimulated the interest by programming in the students. Fig. 8 shows the graph with the results.

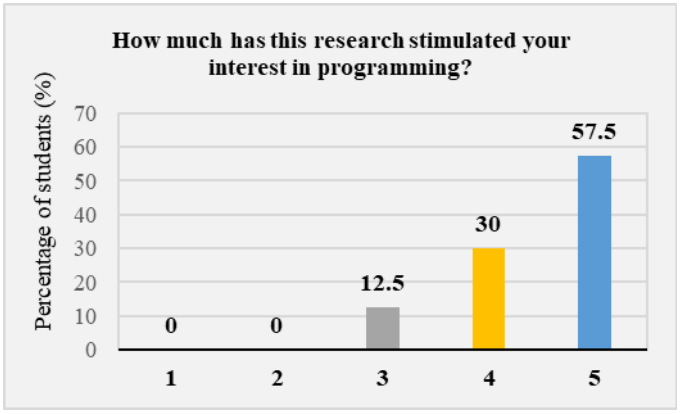

Fig. 8. Students' opinion about how much this research has stimulated interest in programming.

Whenever an activity is used together with a group, some impacts are caused. We can see from Figure 8 that more than participants half responded with the maximum score assigned and, added to the above average score, they reach the percentage of 87.5%. Comparing this result with the percentage sum of Most and Enough, about Interest in Programming, in the Initial Questionnaire, totaling 82.5%, we noticed that there was a small improvement of 5%. Based on this information, we conclude that the research had a positive impact on stimulating interest in programming in participating students, answering to research question.

At the end of the questionnaire, an open space was left for the students to present their suggestions for improvement of presented activities. Table IV shows the suggestions and the percentage of students who answered.

TABLE IV. SUGGESTIONS PRESENTED BY STUDENTS FOR IMPROVED THE ACTIVITIES.

Suggestions	Percentage presented (%)
More activities that stimulate learning in Programming.	50.0
More interaction facilities.	10.0
More clarity in activity.	10.0
Longer educational games.	2.5
More Learning Objects Options.	7.5
Greater clarity in content addressed.	5.0
Provide more levels in games.	12.5
None.	12.5

With the presented suggestions by students, their desire for more activities to stimulate learning was still perceptible, considering that half the suggestions were in this sense. We realized that Learning Objects can play an important role in this process, since the other suggestions are related to their use.

VII. CONCLUSIONS

This study aimed to propose a method called RPOIA for Learning Objects selection, using Petri Nets to model an Intelligent Agent. This method aims to detect the learning profile of students of Programming Logic and suggest LOs to use this profile, with the use of facilitating the concepts understanding and practical discipline applications.

We noticed that Petri Nets allowed to simulate flow of information simply and efficiently, as the answers were provided to questionnaire, shown that they can correctly to create a model of an Intelligent Learning Agent. Based on the presented method, we conclude that Petri Nets are a powerful tool for visualizing dynamic processes with high abstraction. The results were followed by Pipe simulator software, version 4.3.

Results show that RPOIA method was very well evaluated and had a lot of acceptance among students. This shows that these actions make difference to stimulate the students' learning in a discipline considered with some degree of difficulty of assimilation. Also, when compared to how much this research stimulated interest in programming with the degree of initial interest in programming, we noticed that there was a small improvement of 5%, answering the research question proposed this article.

Choice of objects can also influence results. In this research, only two objects were presented for each cognitive profile, which were shown shortly after initial questionnaire. We hope to improve the method for future applications with more options and objects even easier to use, with more interactivity and ease of compression. Also, expand the content to be approached, such as Selection and Repetition Structures, fundamental in programming learning.

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