PROBLEM-BASED LEARNING AS A STRATEGY FOR TEACHING THE FUNDAMENTALS OF KNOWLEDGE REPRESENTATION SYSTEMS: THE EXPERIENCE WITH CELLULAR AUTOMATA

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ABSTRACT
Of an empirical, inter and transdisciplinary character operated by the descriptive qualitative approach, this article aims to describe and analyze a problem-based learning process as a teaching strategy of the Knowledge Representation System discipline. Problem-based learning is an active methodology that has been widely used in the discipline and has guided the entire teaching and learning process in view of the subtheme Cellular Automata and the challenge of understanding the modeling and representation of knowledge implemented by the Turing Machine. Problem-based learning was fundamental in the process, either because of its inter- and transdisciplinary character, or because of its autonomy, which gives students the possibility of managing their learning.

Keywords: Problem-Based Learning. Knowledge Representation Systems. Cellular Automata. Teaching Strategies.

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INTRODUCTION

The search for knowledge and its mobilization is one of the many characteristics of the complex human being. In this context, education, as a science and practice of the processes that involve teaching and learning, has offered several epistemological, theoretical-methodological contributions and its instruments that consolidate an entire culture of approach of how to facilitate teaching-learning-doing-being for the effective development and appropriation of knowledge.

In view of the demands of contemporary life, it is evident that the theoretical assumptions and traditional methods of education, despite their remarkable contributions, are outdated, and, as they are insufficient to meet the current pedagogical and teaching demands, they give way to emerging methodologies, such as those configured in active methodologies.

Problem-Based Learning (PBL) has been presented as an active methodology that focuses on respecting the autonomy of the subject in the management of his learning process, which is built collaboratively with peers who relate to him based on a given challenge (Borochovicius; Tassoni, 2021).

PBL has been widely used in the mandatory curricular component Knowledge Representation Systems (SRC) of the Multi-Institutional and Multidisciplinary Doctoral Program in Knowledge Dissemination (DMMDC), based at the Federal University of Bahia (UFBA).[6] This component presents a curricular proposal that is based on studies of themes located at the interface of cognitive science, semiotics and conceptual modeling with the scope of teaching how human beings model and represent knowledge.

Cellular automata were one of the subthemes of this component, strategically chosen due to their strength of representativeness of patterns that can explain natural phenomena, with effect to biological, cognitive - here inserted the construction and representation of knowledge - and social phenomena which determine, together, human beings (Morin, 2001).

In view of these arguments, the question of how the PBL methodology contributed to the understanding of the fundamental concepts of the SRC component in view of the challenge of representations of patterns of Cellular Automata present in the Conus Textile

[6] The DMMDC emerged in 2003 from collaborative studies between researchers from UFBA and the National Laboratory of Scientific Computing (LNCC), who developed research relating knowledge, society and computational modeling of the Diffusion of Knowledge. It is a graduate program inspired and developed by multi-referential and interdisciplinary approaches. His area of concentration is the modeling of the generation and diffusion of knowledge with a view to the formation of a cognitive analyst based on the construction, diffusion and culture of knowledge that are his lines of research (Federal University of Bahia, c2020).

shell and its implementation in the Turing Machine? worked as the guiding axis of this research.

CELLULAR AUTOMATA AND TURING MACHINE

According to Duch (1995) and Woods (2001), in the PBL active methodology, the problem is used to initiate, direct, motivate and focus the learning of the participants who strive to solve it. In this process, PBL requires the fulfillment of some steps: 1) identify the problem; 2) identify the elements that play a leading role in the problem; 3) to understand the epistemological conceptions that help to assimilate the problem; 4) plan an intervention; 5) carry out the intervention to solve the problem, the result of which can generate a new problem and the cycle can restart (Gonçalves, 2016, p. 6). These steps guided the application of PBL throughout the discipline of CRS, culminating in this research.

In view of this, the problem proposed in the course of finding ways to assemble the shell pattern (Figure 1) by means of the Turing Machine led to the research on Cellular Automata and Turing Machine, epistemological conceptions that are protagonists of the challenge presented.

A Cellular Automaton "is a discrete mathematical model capable of simulating complex behaviors, based on simple rules, based on the theory described by Turing", according to Bezerra (2013, p. 19), citing the works of Turing (1950) and Maria (2003). Also according to Bezerra (2013, p. 19-20), "in abstract terms, a cellular automaton can be defined as a system capable of reproducing standardized behaviors carried out by a homogeneous group of organisms in continuous interaction".

By analyzing this system, it is possible to perceive the existence of some of the following fundamental concepts (Bezerra, 2013 p. 19-20):

- Cell: Smallest unit of the system capable of performing processing based on predefined characteristics, i.e., an automaton;
- Grid (lattice): It is the grouping formed by identical cells, with a predetermined capacity for interaction, ordered in a structural way, that is, a cellular automaton;
- Neighborhood: It is the set of cells in the grid, capable of causing behavioral changes in a univocal way in another cell;
- State: It is the demonstration of the behavior of the cell, that is, its reaction to the activities of its neighborhood;
- Rule: It is the set of information that determines the evolution format of each cell based on the analysis of its neighborhood.

When analyzing the concepts that make up the Cellular Automata, it is important to briefly contextualize history, which makes it possible to understand the advances in research on the subject, its main responsible, and the contributions of this theme to various areas of knowledge, the theoretical basis necessary to solve the proposed challenge.

According to Dias (2021, p. 74), the origin of Cellular Automata dates back to the 30s of the last century, a context marked by the development of areas such as computation theory, information theory, cybernetics, and systems theory. In 1936, mathematician Alan Turing developed a theoretical device called the universal machine or Turing machine, which consisted of "a mathematical model, based on finite automata, composed of a finite group of symbols, a finite number of states, and a ribbon of unlimited length divided into small cells arranged in sequence." (Bezerra, 2013, p. 18).

The Turing Machine is considered a milestone in the evolution of science, since, even though it is only theoretical, it is one of the foundations of Computer Science and the basis of the theory of cellular automata and the concept of one-dimensional cellular automaton. Being, "to date, the application of his idea of infinite tape used to guide the resolution of edge problems for cellular automata at n dimensions" (Bezerra, 2013, p. 18).

John von Neumann (1903-1957), a mathematician, naturalized American and of Hungarian origin, began the study of this important computational tool in the 40s, whose proposal was presented at the Hixon Symposion, on September 20, 1948 (Gabrick, 2021, p. 20).

In the early 1950s, the studies of mathematician Stanislow Ulam (1909-1984) and Von Neumman to design artificial mechanisms of self-reproduction stand out. Neumann was trying to create a system that would replicate itself. Ulam, who was studying the formation of crystals through a model of a lattice and cells, suggested that he use this type of model. Thus, a first example of a Cellular Automaton was born, which, although the automaton defined by von Neumann was relatively complex, "formally fulfilled the role of machines capable of generating replicas of themselves" (Dias, 2021, p. 75).

RESULTS AND DISCUSSION

The curricular component Knowledge Representation System, already evidenced above, was developed based on PBL, with its characteristics well evidenced throughout the process of understanding and solving the proposed central problem. This problem consisted of the discovery of a cellular automaton that could represent the patterns existing in a Conus Textile seashell, which is a beautiful, variable and very popular species, drawing attention mainly for the patterns expressed on its surface.

Figure 1. Example of Conus Textile seashell with triangle pattern

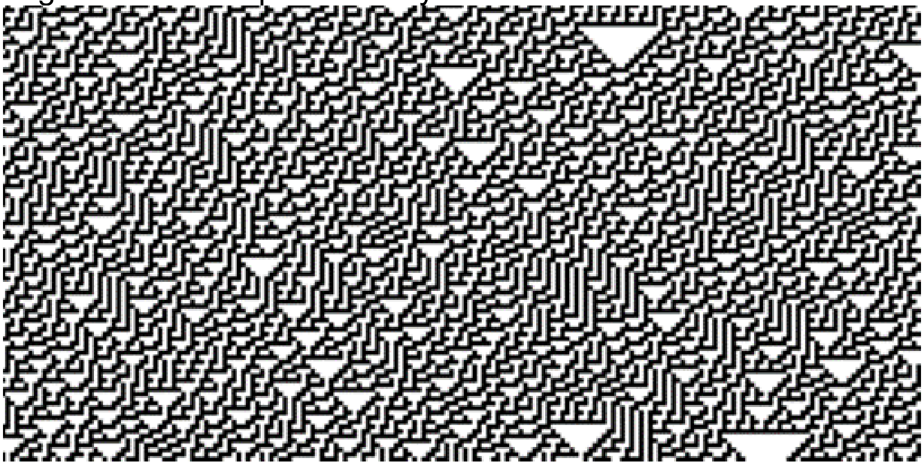
Cast iron: Richard Ling (2005).

Following the perspective of PBL for the resolution of the central problem, some steps were outlined, with the intention of facilitating the search for viable solutions by building a pattern similar to that of the shell. To this end, it was necessary to deepen the "Cellular Automata" category, which can be carried out through a systematic investigation of the historical context, which characterized Stage I, of search for the construction of a representative model. Along with the understanding of the importance of Cellular Automata, the advances provided by the Turing Machine are inseparably linked, which, in an accessible way, can generate models of complex representations.

In view of the knowledge acquired in this initial stage, of building a Cellular Automaton, we started to attempt the computational representation of this natural pattern, which characterized Stage II.

For this moment, knowing that each cell secretes pigments according to the segregation (or absence of segregation) of its neighboring cells and the set of cells produces the pattern of the shell as it grows (Melotti, 2009), it was possible to identify a great similarity of this pattern with that of a Cellular Automaton with rule 30, of Wolfram.

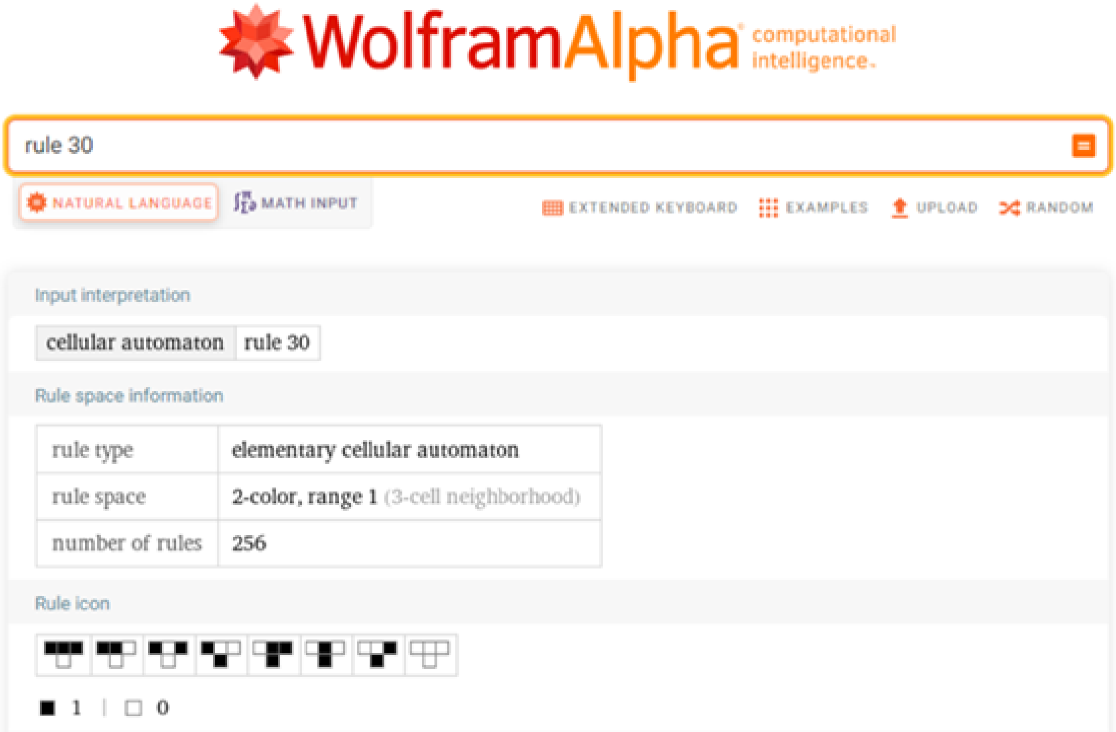
Figure 2. Pattern produced by a Cellular Automaton with rule 30



Fonte: Wolfram Alpha (c2022).

This identification arises from the moment that other patterns, generated by different rules, have been tested and refuted, which can be understood as a fundamental part of PBL, in which the subject actively participates in his or her learning process. Regarding this stage of identification of the rule that generates the shell pattern, in view of the expected practicality, the WolframAlpha computational knowledge mechanism was used, a freely accessible site, which provides answers to the most varied demands. For this case, some rules were tested and visualized, until the identification of rule 30, as follows:

Figure 3. Rule 30 View from WolframAlpha



Fonte: Retirado do site < https://www.wolframalpha.com/>.

The identification of the eight rule icons was fundamental for the construction of the Cellular Automaton to be advanced, based on the aforementioned rule 30. Such construction required a broad knowledge about the Turing Machine and its operation, since the implementation of the identified pattern should occur in it. To this end, in this scenario of knowledge representation, another important tool emerges, which is Visual Turing, an editor and graphic simulator that reproduces, in a virtual way, the machine creation/association environment of the conventional Turing Machine.

The implementation of the rule icons in Visual Turing characterizes, initially, the realization of Step III, which deals with the construction of one of the rules of a Cellular Automaton in the Turing Machine. For this case, the constructed rule goes against the solution initially proposed by the curricular component in question, of representation of the pattern present in the shell.

Rule icons were initially implemented through logical sequences such as:

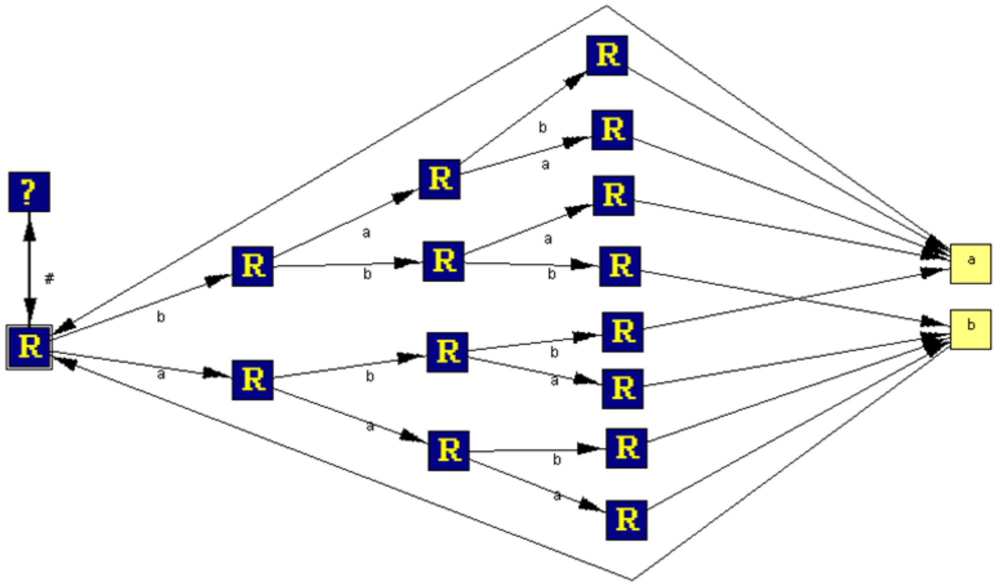
Table 1. Logical Sequences for Implementing Rule 30 Icons in Visual Turing

A	B	C	S= A+B+C
1	1	1	0
1	1	0	0
1	0	1	0
0	0	0	0
1	0	0	1
0	1	1	1
0	1	0	1
0	0	1	1

Source: Elaborated by the authors.

Adopting 1=a and 0=b, such logical sequences gave rise to the following machine:

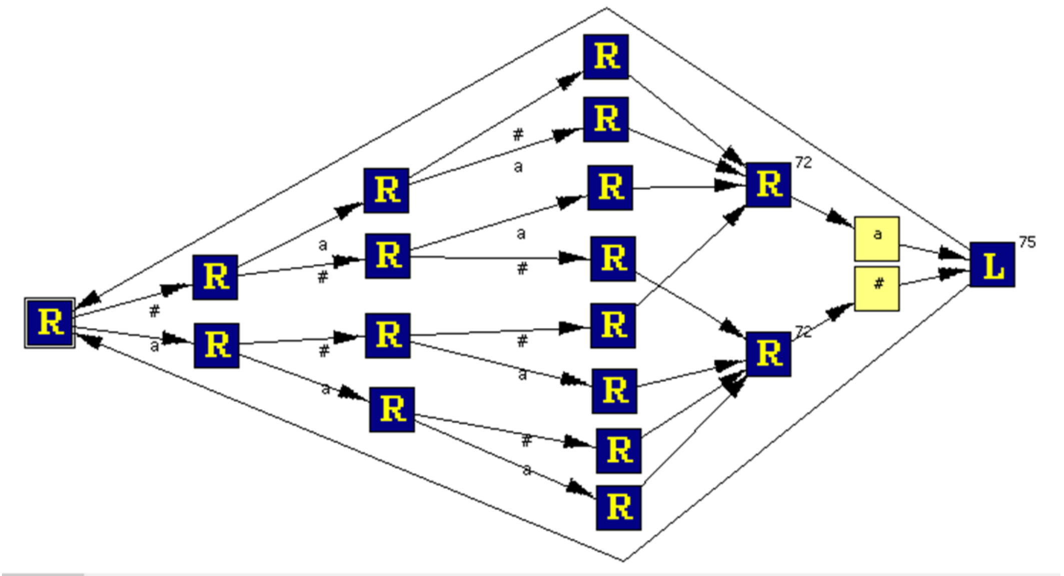
Figure 4. Logical Sequences for Implementing Rule 30 Icons in Visual Turing



Source: Elaborated by the authors.

The machine expressed in Figure 4, created in the virtual environment of Visual Turing, reflects an important step in the construction of the Cellular Automaton with a pattern similar to that present in the shell. From the attempts at improvement and the direct application of the functions found in the area of creation of the virtual environment, it was possible to create a Cellular Automaton, based on rule 30, capable of reproducing the pattern of the shell.

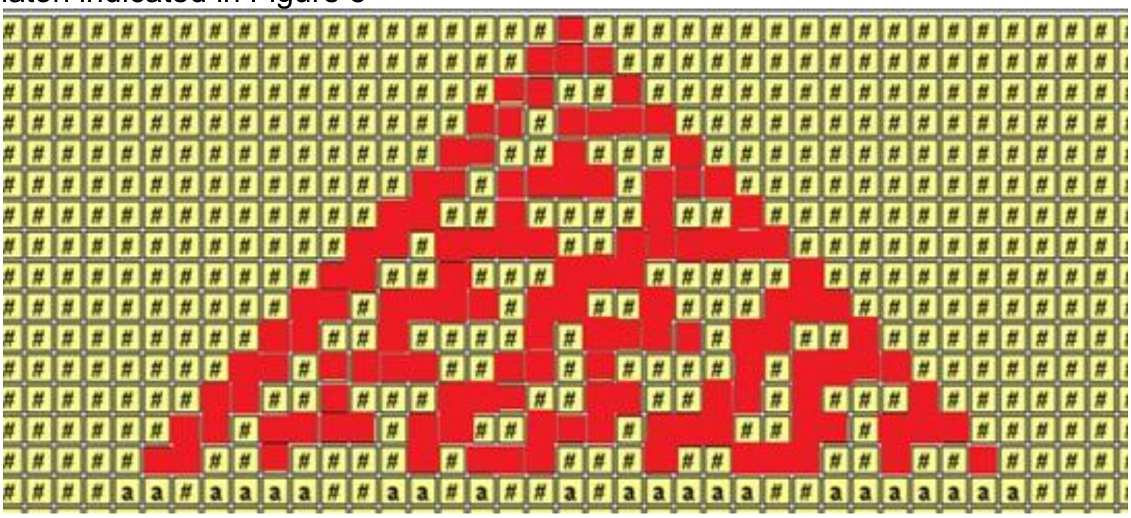
Figure 5. Final machine, with changes, to run in Visual Turing



Source: Elaborated by the authors.

Figure 5 indicates a model of knowledge representation, implemented in the Turing Machine, represented here by Visual Turing. It is a representative model that expresses the creation of a Cellular Automaton based on rule 30 and its rule icons. The execution of such an Automaton, in the virtual environment, generates the pattern present in the shell, partially satisfying the requirements of the problem proposed by the curricular component.

Figure 6. Rule 30 pattern generated in Visual Turing after running the Cellular Automaton indicated in Figure 5



Source: Elaborated by the authors.

The free construction and direct action of individuals in the development of this representative model reflect important characteristics of PBL as a methodology that can enter different contexts and levels of education. The division into groups for the creation of the Cellular Automaton made other elements be perceived, such as the possibility of working cooperatively and stimulating the development of social skills in the subjects involved with the solution of the proposed problem.

Mixing theory and practice, throughout the learning process, PBL becomes an efficient teaching methodology in the classroom context, once the engagement of the subjects in the search for viable solutions is verified. A more comprehensive way of teaching and learning is observed, leaving the uniterality of the educational process and removing from the teacher the total responsibility for conducting learning, as everyone can act actively and occupy the various spaces.

FINAL CONSIDERATIONS

In addition to understanding the importance of cellular automata and the Turing machine for conceptual modeling, with regard to the representation of knowledge, the mastery of tools such as Visual Turing becomes fundamental due to the creative possibilities they offer. The search for the solution of the initial problem of the component through PBL, the construction of the cellular automaton with a pattern similar to that of a Conus Textile marine shell, brings to light its methodological potential for the educational sphere, since it prioritizes the autonomy of the subjects and the possibilities of creation during the process of construction and representation of knowledge in a virtual environment.

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