Unplugged computing and computational thinking: approaching the subject as an Extension Curricular Unit

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Abstract. Introduction*: Software Engineering education requires the development of both technical and interpersonal skills, making it essential to adopt more practical and participatory approaches. In this context, Project-Based Learning (PBL) has emerged as an effective strategy to foster greater engagement and the practical application of course content.* ***Objective****: This study aims to report the experience of applying PBL in the Software Engineering I course of a Computer Science undergraduate program at a public institution.* ***Methodology****: The research followed an action research approach, involving questionnaires, interviews, and participant observation. Students developed real-world projects, progressing through stages such as requirements elicitation, modeling, and prototyping.* ***Results****: The data revealed increased student engagement, development of technical and socio-emotional skills, and a positive evaluation of the methodology by participants.*
Keywords *Unplugged computing, Computational thinking, Analog games, Computer science education, Gamification.*

1. Introduction

As society continues to advance, new creations and modernizations appear every day, and the way we do things like communicate, get around and teach has changed over the years. In the past, long-distance communication was done through letters or even a telegram, and today we can communicate with someone on the other side of the world through video calls and messages in a matter of seconds.

In recent years, Brazilian higher education has undergone a significant expansion process in terms of access and coverage. According to the Higher Education Census [INEP 2024], the country has surpassed the 9.9 million mark in undergraduate enrollment, with 79.3% concentrated in private higher education institutions and 20.7% in public institutions. Despite this growth, the net schooling rate for the population aged 18 to 24 remains at 21.6%, indicating that a significant proportion of young people are still out of university. This scenario reveals advances in the expansion of the supply, but also exposes challenges related to the democratization of access, permanence and completion of courses in Brazilian higher education.

Despite the expansion of access to higher education in recent years, the challenges related to pedagogical practices remain evident. Still on the subject of the 2023 Census, the data reveals that only 41% of face-to-face students complete their courses after ten years, while in distance learning this rate drops to 33%. Dropout rates are equally worrying: 58% in face-to-face courses and 66% in distance learning. These figures indicate that the use of digital technologies and the growth in remote provision have not, on their own, guaranteed improvements in educational results. In many courses, the teaching model is still centered on the presentation of content, with limited student participation and little adoption of active methodologies. Given this scenario, it is essential to look for more participatory and accessible approaches, capable of promoting greater engagement and the development of skills such as computational thinking. In addition, the lack of knowledge on the part of many teachers about active methodologies and innovative teaching strategies can compromise student engagement, generating feelings of fear, anxiety and frustration in the learning process [Rodrigues Júnior et al. 2006].

These approaches, due to their expository and non-interactive nature, often make studying monotonous and demotivating, especially for students who demand more dynamic and participatory stimuli [Wang e Eccles 2013]. To overcome this scenario, it is necessary to incorporate practices that encourage student protagonism and active engagement in the learning process.

In this context, one approach that has gained prominence in the current educational scenario is Unplugged Computing, which offers an accessible and fun alternative for teaching computer concepts. Among various initiatives aimed at stimulating Computational Thinking, Unplugged Computing has been described as a method that is widely accepted by teachers and students. It promotes a way of making teaching more attractive by incorporating games and interactive dynamics that teach the fundamentals of Computer Science without the need to use computers.

Various resources have been organized and made available to support the implementation of Unplugged Computing in educational contexts. Among them is the material from the *Unplugged Computing and Computational Thinking* project, which brings together structured activities to work on concepts such as algorithms, data structures and logic, in an uncomplicated way and without the use of digital devices [Bell et al. 2015]. These resources help teachers to incorporate the approach into the classroom, adapting it to different teaching levels and school realities.

Today, society is immersed in digital technologies, especially the constant consumption of media such as videos and social networks. This scenario represents an opportunity to increase the visibility of innovative educational practices. In this sense, digital media can be used as a means of disseminating Unplugged Computing, facilitating access to materials and encouraging their adoption by teachers and students.

The aim of this paper is to develop and disseminate analog games that address computing concepts in an unplugged way, with a focus on promoting computational thinking among higher education students. The proposal also aims to make this educational content accessible through digital media, broadening its possibilities of application in different pedagogical contexts.

The relevance of this study lies in the fact that Unplugged Computing and Computational Thinking address educational realities in which access to computers is limited or non-existent. This approach makes it possible to teach the fundamentals of Computing without the need for a machine, valuing logical reasoning, abstraction, problem solving and understanding algorithmic structures. In addition, its interdisciplinary nature allows for links with other areas of knowledge, expanding its pedagogical potential.

2. Related Work

Several studies have explored alternative approaches to teaching computational concepts, especially Unplugged Computing and its application to the development of Computational Thinking. Although this paper focuses on higher education, significant contributions have also been identified in other stages of education, such as basic education and initial teacher training, whose findings proved relevant to the construction of this research. Thus, this section brings together research that discuss conceptual definitions, pedagogical methodologies and practical experiences related to these themes, with an emphasis on higher education, but also including occasional clippings from other educational segments that help to deepen the analysis.

2.1. Conceptual Approaches and Definitions

Unplugged Computing has gained prominence in the literature as a promising pedagogical approach for the development of Computational Thinking (CT), considered an essential skill for the 21st century. [Papert 1980], in a pioneering perspective, already anticipated this vision by proposing the use of programming as a tool for building logical reasoning, especially through the LOGO environment, highlighting the role of experimentation and creativity in the learning process. Initiatives such as [Bell et al. 1998] and [Bell et al. 2011] reinforce this concept by offering playful and accessible activities that explore computational concepts without the use of computers. In the Brazilian context, studies such as those by [Rodrigues et al. 2018] and [Pereira et al. 2019] highlight the importance of CT not only in computer training, but also in other areas of knowledge, emphasizing its potential to foster creativity, autonomy and critical thinking, including in higher education.

2.2. Reasons for using Unplugged Computing

Unplugged Computing (UC) has become a didactic alternative that expands the possibilities for teaching computational concepts, especially in educational realities with technological restrictions or that value methodologies based on the active participation of students. [Bell et al. 2011] base their proposal on the possibility of working with logic, algorithms, cryptography and other structures without relying on digital equipment. This approach makes learning more accessible and encourages student involvement.

[Rodrigues et al. 2018] and [Pereira et al. 2019] report that UC favors educational environments that are more open to experimentation, cooperation and the experience of error as part of the learning process. In higher education, [Vieira et al. 2013] show that UC helps to demystify computing, making concepts such as object orientation accessible. [Oliveira et al. 2021] also defend UC as a tool aligned with the National Common Curriculum Base (BNCC) and highlight its use in undergraduate courses, both for learning and pedagogical training.

2.3. Experiences in Different Stages of Education

Several experiences described in the literature demonstrate the applicability of Unplugged Computing at different levels of education, with initiatives in higher education standing out, but also with significant contributions to basic education and teacher training.

[Mourão et al. 2025] describes the application of analog games in introductory Object-Oriented Programming courses. The activities were designed to mediate the understanding of concepts such as classes, objects and methods, facilitating the transition from abstract thinking to coding practice. [Oliveira et al. 2021] report on the use of UC in teacher training actions in undergraduate courses, through workshops, programming clubs and articulating curricular components. In these experiences, university students acted both as apprentices and as mediators in activities with basic education schools, broadening their didactic training and promoting Computational Thinking in an interdisciplinary and contextualized way. Although the main focus was on basic education, the study by [Vieira et al. 2013] directly involved university students from Computer Science, Information Systems and Software Engineering courses in creating and conducting plays based on the fundamentals of UC. These students took part as actors and facilitators in the activities developed with primary and secondary school students, experiencing active learning, citizen education and practice in communicating computer content.

2.4. Methodologies, Evaluation Tools and Reported Impacts

The literature analyzed presents a diversity of methods, including case studies, classroom interventions, controlled experiments and systematic reviews. [Rodrigues et al. 2018] identify the recurrent use of questionnaires, participant observation and performance analysis as assessment tools, but also point out the need for greater standardization. [Pereira et al. 2019] propose the use of continuous activities, qualitative feedback and collaborative corrections to monitor student progress.

In terms of impact, [Vieira et al. 2013] reports high student engagement in drama activities based on Unplugged Computing, with gains in understanding and retention of content such as cryptography and sorting. The study also highlights the students' emotional and motivational involvement. In higher education, reports point to greater conceptual clarity and confidence in learning OOP, with reduced dropout and improved performance in introductory subjects [Rodrigues et al. 2018], [Mourão et al. 2025].

3. Methodology

This study is characterized as qualitative, exploratory, and applied, with complementary use of quantitative data. Initially, a literature review was conducted using national and international scientific databases, aiming to identify and analyze different approaches to Unplugged Computing. This review enabled the construction of a solid theoretical foundation, from which previous studies were compared, highlighting the most relevant conceptual, methodological, and practical aspects for delimiting the research problem and supporting the proposed approach.

Subsequently, a case study was carried out involving higher education students and instructors, in which activities based on analog games aligned with the Unplugged Computing methodology were implemented. According to [Maia et al. 2020], exploratory case studies are suitable for investigating underexplored phenomena, allowing

the identification of multiple relevant aspects when there is still a lack of systematized information on the subject.

To support the analysis of results, structured questionnaires were applied to gather participants' perceptions regarding conceptual clarity, engagement, and the pedagogical contribution of the activity.

4. The Project

The *Unplugged Computing and Computational Thinking* project was carried out over two academic terms as part of the Extension Curriculum Unit (ECU) of the Computer Science program at State University of Rio Grande do Norte – UERN. The activities were led by a group of undergraduate students, under the supervision of a faculty advisor, and were organized into biweekly in-person meetings starting in May 2024. The following phases detail the methodological path adopted, from the theoretical foundation to the development and validation of the analog games created.

4.1. Literature Review and Theoretical Foundation

The starting point of the research was a literature review on Unplugged Computing and its pedagogical applications. Sources included Google Scholar, the CAPES Journals Portal, and the institutional repositories of USP, UFRJ, and the Brazilian Computing Society (SBC). The inclusion criteria focused on open-access papers that directly addressed activities, pedagogical strategies, or implementation results of Unplugged Computing. This process enabled the construction of a theoretical framework to support the game design stage and the definition of the project's educational goals.

4.2. Game Ideation and Theme Definition

The next phase involved brainstorming sessions to define the themes to be addressed in the games and strategies for disseminating the produced materials. The meetings were held in person, with an average participation of 8 to 10 students per session. Ideas were discussed collectively and recorded on whiteboards, fostering a collaborative design environment.

The selection of themes was based on two main criteria: the participants' affinity with Computer Science domains and the pedagogical feasibility of each topic. Highly complex subjects or those requiring extensive prior knowledge, such as graph algorithms involving loops and logical conditions were avoided. In such cases, more accessible and conceptual approaches were chosen, ensuring the didactic coherence of the game.

4.3. Game Design and Development

Once the themes were defined, the groups were organized to design the games based on digital game design principles as proposed by [Rogers 2013], adapted to the analog context. Each group was responsible for outlining, designing, and creating playful mechanics that addressed the selected computational concepts through unplugged activities.

During in-person meetings, the proposals were presented to other participants, who provided suggestions for adjustments and improvements. Graphic design and layout software were used to develop the visual elements and layout of the materials, allowing for greater aesthetic refinement and clarity in the visual instructions of the games.

4.4. Prototyping and Playtesting

After the design phase, physical prototypes of the games were created using materials selected by each group. Subsequently, playtesting sessions were conducted with individuals external to the project, aiming to evaluate the clarity of the instructions, the functionality of the mechanics, and the alignment between the intended objectives and the actual gameplay experience.

These tests provided feedback for prototype refinement, including rule restructuring, improvements in material accessibility, and adjustments to the level of challenge. This phase ensured that the games were suitable for real educational contexts.

4.5. Manual Production and Exhibition Organization

After final adjustments to the prototypes, each group prepared an instructional manual containing the necessary guidelines for implementing the games in the classroom. The materials were standardized and organized in a clear and accessible manner, aiming to facilitate their use by teachers and other stakeholders interested in applying the activities in educational settings. Figure 1 below illustrates the final products of the project, including game boards, cards, and other physical components of the games.

Figure 1. Boards and physical materials of the analog games developed during the project.

As the final stage of the development process, an in-person exhibition of analog games was organized with the aim of showcasing the developed products, promoting interaction with the academic community, and collecting participant feedback. The exhibition featured the six games created during the project, described as follows:

- **Algoritmia Quest**: A board game with cards designed to support learning of algorithms, data structures, hardware, logic, and theoretical computer science.

Four players compete, and the winner is the first to reach the final square on the board by correctly answering questions.

- **Bug Quest**: A board game with cards focused on the use of loops and sequencing. Players use commands to move their pawns and remove "bugs" from the system, earning points based on the color of the eliminated bugs. The player with the highest score at the end of the game wins.
- **Caça ao Tesouro**: Based on the concept of finite state automata, this game challenges players to find the shortest path to Treasure Island. The winner is the one who reaches it first using the shortest route.
- **Labirinto**: Focused on teaching basic concepts of programming and logic, this game presents challenges involving the construction of algorithmic solutions.
- **Logikards**: A card game for two to four players that stimulates logical reasoning through symbolic logic and strategy challenges.
- **Decifrando a Mensagem em Código Binário e Adivinhação Binária**: Games aimed at teaching the fundamentals of the binary system, addressing rules, patterns, and properties of binary numbers in a playful way.

The exhibition was attended by faculty and students from the Computer Science program, many of whom were not yet familiar with Unplugged Computing. There was continuous interaction with the developers, and the public responded positively asking questions, testing the games, and suggesting potential applications in various educational contexts. Several participants expressed interest in using the games as pedagogical tools, reinforcing the potential of the approach, as illustrated in Figure 2.

Figure 2. In-person exhibition of analog games: participation of faculty and students testing the developed games.

Although this was the first edition of the game fair organized by the project, the event received good participation and acceptance, contributing to both the social and

pedagogical validation of the developed materials. The exhibition was also promoted through social media posts, which helped expand the reach of the initiative and encouraged its dissemination among other institutions and educators.

5. Evaluation and Results

To assess the reception and effectiveness of the developed games, a structured questionnaire was administered, gathering 40 responses from higher education students, teachers, and external participants who played the games during testing sessions. The instrument included twenty objective criteria, organized into four main categories—playability, attractiveness, difficulty, and complexity each evaluated on a 1-to-5 scale. Additionally, open-ended questions were included, allowing participants to express qualitative perceptions regarding the strengths of the games, areas for improvement, and suggestions for enhancement. This combination of quantitative and qualitative data enabled a more comprehensive analysis of user experience with the developed games.

The data obtained reveal an overwhelmingly positive evaluation of the games. The highest-rated criteria were “rule structure” (4.63), “clarity of rules” (4.60), “challenge appropriateness” (4.60), and “suitability for the target audience” (4.60). These results indicate that the games were well understood by participants, offering clear rules, challenges appropriate to the educational context, and alignment with the student profile.

In addition to revealing positive acceptance, the highest-rated criteria highlight important aspects of the pedagogical role of the games. “Clarity of rules” and “challenge appropriateness” indicate that participants were able to understand the objectives of the activities and engage with them fluidly, an essential factor for focusing attention on content learning rather than on the operational complexity of the gameplay. “Intuitiveness” and “gradual learning,” in turn, suggest that the games supported a progressive conceptual construction aligned with principles of active learning and the development of computational thinking. These findings indicate that the games functioned not only as playful tools, but also as didactic mediators capable of fostering logical reasoning, abstraction, and problem-solving, as proposed by authors such as [Bell et al. 2011] and [Vieira et al. 2013].

Other well-rated aspects included “intuitiveness” (4.57), “visual accessibility” (4.50), “structural coherence” (4.45), and “exploration capacity” (4.45), reinforcing the balance between aesthetics, internal organization, and the ability to provide varied experiences to players. Interactivity (4.37) and gradual learning (4.35) were also positively assessed, suggesting that the games promote progressive engagement and active participation.

On the other hand, the lowest-rated criteria were “conceptual richness” (3.75), “replayability” (3.85), and “originality” (3.95). These results indicate opportunities for improvement, suggesting that the games could be enhanced in terms of conceptual depth, replay value, and innovation in gameplay mechanics.

In addition to the quantitative data, the open-ended responses revealed positive impressions regarding ease of understanding, player interaction, and the enjoyment provided by the proposed dynamics. Among the improvement suggestions, participants

highlighted the need to increase the variety of cards and visual elements to help differentiate similar symbols. Other suggestions included adding new features and game modes.

Overall, the results demonstrate that the analog games based on Unplugged Computing were well received by the university audience, contributing to the development of a solid conceptual foundation, fostering engagement, and sparking interest in computing. The evaluation underscores the potential of playful approaches in higher education as effective strategies for mediating the learning of abstract concepts and stimulating skills associated with Computational Thinking.

5.1. Considerations on Learning and Cognitive Development

Although the evaluation focused on aspects such as clarity, appeal, and usability, these criteria provide evidence of the potential of games to support the learning of computational concepts. The clarity of the rules and the positively rated gradual learning contribute to the understanding of procedures and content, as discussed by [AUSUBEL et al. 1978].

These findings align with studies such as [Vieira et al. 2013], which emphasize the role of playful activities in conceptual retention and in stimulating logical reasoning. The problem-solving mechanics and challenges embedded in the games involve skills such as abstraction and pattern recognition, which are central to Computational Thinking [Bell et al. 2011].

Even without directly measuring cognitive performance, the results suggest that analog games can actively mediate the learning process in higher education.

6. Critical Discussion and Limitations

The results indicate positive reception of the games in terms of clarity, usability, and engagement. However, the absence of formal assessment instruments limits the ability to confirm cognitive impacts. Furthermore, the games were applied in a limited context, with a small sample and no control group.

Despite these limitations, the experience highlights the potential of Unplugged Computing as a viable pedagogical resource, especially in environments with low technological infrastructure. For future studies, it is recommended to apply the games longitudinally in curricular courses, using diagnostic tests and comparative analyses between groups.

These developments may contribute to consolidating the approach as a complementary strategy for teaching computing in higher education.

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