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Gamified learning tools and technology in education: a systematic exploration study of programming tools during the pandemic

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Abstract: Programming is vital for nurturing logical thinking, problem-solving, and effective decision-making in an increasingly digital world. Gamification plays a crucial role in education by integrating game elements to enhance engagement and motivation, particularly during times like the pandemic. In this context, teaching programming with a gamified approach not only makes learning enjoyable and engaging but also fosters problem-solving and logical thinking skills. This study aims to conduct a systematic literature review, focusing on the significant challenges and opportunities in teaching programming, particularly with block programming tools like Scratch. Initially, 104 articles were identified, with 33 selected for in-depth reading, and ultimately, 23 articles were analyzed, originating from 22 countries. The majority of articles highlight positive outcomes, including student progress, collaboration, and increased engagement. However, some studies point out limitations, such as a lack of focus and neglect of serious games in education.

Keywords: COVID-19 pandemic; block programming, logical thinking, Scratch, systematic literature review, engagement.

Ferramentas de aprendizagem gamificada e tecnologia na educação: um estudo sistemático de exploração de ferramentas de programação durante a pandemia

Resumo: A programação é vital para nutrir o pensamento lógico, a resolução de problemas e a tomada de decisões eficaz em um mundo cada vez mais digital. A gamificação desempenha um papel crucial na educação, integrando elementos de jogos para aumentar o engajamento e a motivação, principalmente em tempos de pandemia. Nesse contexto, ensinar programação com uma abordagem gamificada não apenas torna o aprendizado agradável e envolvente, mas também promove habilidades de resolução de problemas e raciocínio lógico. Este estudo tem como objetivo realizar uma revisão sistemática da literatura, focando nos desafios e oportunidades significativos no ensino de programação, particularmente com ferramentas de programação em blocos como o Scratch. Inicialmente, foram identificados 104 artigos, sendo 33 selecionados para leitura aprofundada e, ao final, foram analisados 23 artigos, provenientes de 22 países. A maioria dos artigos destaca resultados positivos, incluindo progresso do aluno, colaboração e maior envolvimento. Porém, alguns estudos apontam limitações, como falta de foco e descaso com os serious games na educação.

Palavras-chave: Pandemia COVID-19; programação em bloco, pensamento lógico, Scratch, revisão sistemática da literatura, engajamento.

1. Introduction

Programming is crucial for logical thinking, involving ordered instructions to solve complex problems. Crafting algorithms and code structures challenges individuals to organize information and anticipate outcomes, fostering analysis and problem-solving. This logical thinking is vital beyond programming, empowering informed decisions,

recognizing patterns, and deducing relationships for effective decision-making (LIMA; FERREIRA and SILVA, 2021; SENDACZ; ISOTANI and LIMA, 2023).

Gamified tools like Scratch play a key role in teaching programming and computational thinking in schools. Especially during COVID-19, interactive games and challenges promote active learning, motivation, and engagement. Gamification provides an intuitive, enjoyable environment, particularly for young students. Scratch offers direct visual understanding of instructions, enhancing learning. Projects in Scratch develop problem-solving, logical thinking, and creativity. Gamification eases programming anxiety, fostering a positive learning mindset and transferable skills. Integrating tools like Scratch equips students for the digital era (LIMA and ISOTANI, 2022).

Systematic Literature Review (SLR) identifies and analyzes articles meeting criteria for comprehensive analysis. Our SLR employed the StArt Tool*(FABBRI *et al.*, 2016; FABBRI *et al.*, 2012; HERNANDES *et al.*, 2012), based on prior mapping studies (KITCHENHAM *et al.*, 2009; KANDLHOFER and STEINBAUER, 2016; LIMA and ISOTANI, 2022). This work employs SLR to identify key studies using gamified or block-based tools for teaching computational thinking and programming logic to all age groups during the pandemic. The research covers global articles, highlighting challenges and opportunities during pandemic teaching.

2. Methodology

In this work, SLR was divided into three main stages: (1) planning, (2) execution and (3) summarization. Each step was divided into three steps, totaling nine substeps, as can be seen in Figure 1. At this stage, we develop two research questions for guiding

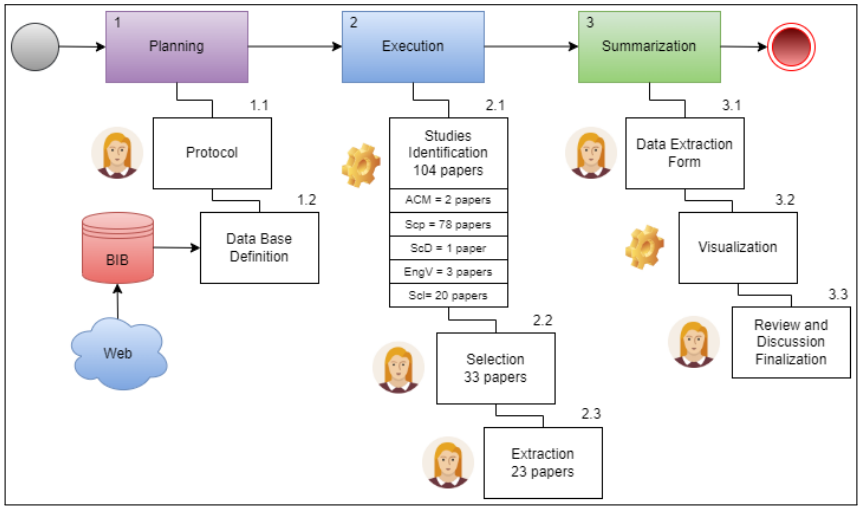


Figura 1. Procedure for conducting systematic literature review, doll icons depict manual execution, gear icons symbolize automated execution.

the systematic literature review. To address these, we utilized data mining methods, particularly clustering strategies, to find articles with notable similarities: (1) How did gamified programming aid students during the pandemic? (2) What were the primary challenges faced?

2.1. Planning

This planning stage was divided into two main phases. The first phase comprises the manual elaboration of the research protocol, while the second involves the automated

*Developed by the Software Engineering Research Laboratory at the Federal University of São Carlos (UFSCAR). Download: ⟨https://www.lapes.ufscar.br/⟩.

extraction of data from the implementation of the outlined protocols. Online repositories provide a range of articles that are later aggregated into a database in the `.bib` format. This database, in turn, is used in subsequent phases of the RSL process.

2.1.1. Protocol

The planning stage involves the formulation of the research protocol destined to conduct the RSL. In this scenario, the search string was configured to cover all terminology related to the core keywords: TITLE-ABS-KEY (Scratch `AND` (gamification `OR` gamified `OR` ludic `OR` serious games `OR` games) `AND` (computational thinking `OR` programming logic `OR` logical reasoning `OR` logic abstraction) `AND` (students `OR` student) `AND` (pandemic `OR` Covid-19 `OR` coronavirus `OR` Covid `OR` Sars-cov-2 `OR` lockdown)) `AND` (LIMIT-TO (2020, 2021 and 2022)). Additionally, we developed a form for data extraction, aiming at simplifying the analysis of results.

2.1.2. Inclusion and Exclusion Criteria

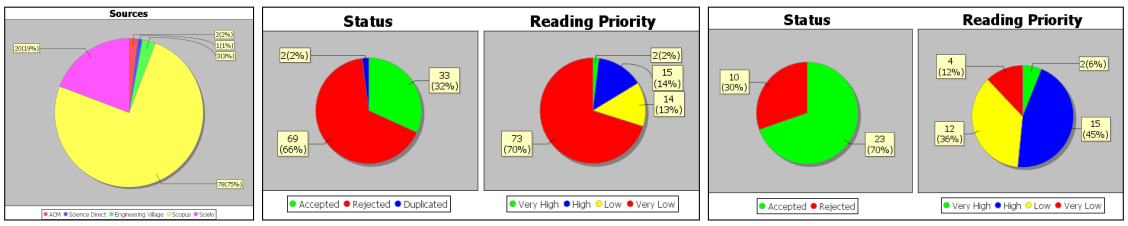
We used the following databases: ACM, Scielo, Science Direct, Engineering Village, and Scopus. All obtained articles were refined using the StArt app (available and accessible in the StArt mechanism). In this phase, inclusion and exclusion criteria were established. Inclusion criteria (I) adopted were: (a) articles in English, (b) peer-reviewed, (c) correctly loaded in the StArt database, (d) data analysis guidelines, (e) published in the last 3 years, and (f) categorized as primary studies. For exclusion criteria (E), we considered: (a) articles where Scratch approach wasn't related to education, (b) articles without involving a group, (c) articles not addressing Scratch or other block programming, and (d) articles exclusively on pandemic programming.

2.2. Execution

This section focuses on performing the SRL, with 3 main steps, identification of studies, selection (reading the TAK) and extraction (reading the full paper).

2.2.1. Studies Identification

When examining the results, notable variations emerged in the article counts across databases. For instance, the ACM database yielded only 2 articles, while Scielo featured 20 articles. Science Direct returned 1 article, and Engineering Village contributed 3 articles. Conversely, Scopus produced the highest count with 78 articles. These findings, depicted in Figure 2(a), imply that the distribution of articles among databases may be influenced by factors like thematic coverage and the relevance of search terms.



(a) Studies Identification. (b) Selection. (c) Extraction.

Figura 2. Percentual dos 104 artigos que foram identificados na pesquisa em bases científicas.

2.2.2. Selection

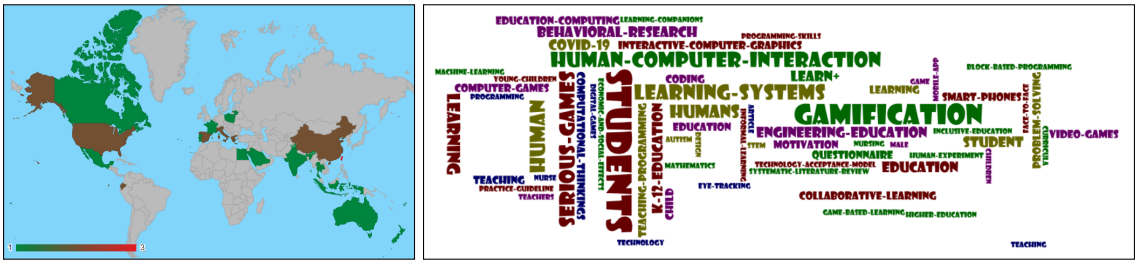
After identifying the 104 articles, the selection stage is carried out for a more refined screening. At this stage, as shown in Figure 2(b), 33 articles (32%) were considered eligible according to the inclusion criteria, while 69 articles (66%) were discarded based on the exclusion criteria. In addition, 2 articles (2%) were identified as duplicates, even with different titles, the duplication being checked manually. Consequently, the reading priority was established as follows: the 70% articles were classified as very low reading priority, as they did not meet any of the selection criteria. In addition, 13% of the articles were classified as low reading priority, 14% as high reading priority, and 2% as very high reading priority.

2.2.3. Extraction

The representation of the extraction step is illustrated in Figure 2(c). Within the set of 104 articles analyzed, a total of 23 articles (70%) were identified for the extraction phase and considered accepted, while 10 articles (30%) were rejected. The values presented by StArt after extraction are represented in Figure 2(c).

2.3. Summarization

In this section, we offer a concise overview of the SLR on Scratch as a gamification tool. This step distilled key info from selected articles in the SLR, presenting it clearly. Herein we also present the visual representations of the SLR data on Scratch as a gamification tool, see Figure 3. These visualizations are crucial for understanding the results and extracting significant insights. Figure 3(a) shows the analysis of global



(a) World map. (b) Cloud of Words.

Figura 3. Visualização de dados a partir da RSL.

Scratch usage highlights diverse contributions, with the United States and Taiwan leading in interest and research. Several other countries also participate, showcasing widespread adoption of this strategy. Greece, Italy, China, Ecuador, and Spain exhibit substantial involvement, boasting multiple publications. This demonstrates a sustained commitment and extensive research in the field of Scratch-based gamification during pandemic situations. The word cloud in Figure 3(b) highlights the main keywords of the articles, such as students, gamification, human-computer interaction, learning systems, serious games, behavioral research, human and education. These terms reflect the importance of a playful and interactive approach to learning with the use of Scratch as a gamification tool.

2.4. Theoretical Framework

The Table 1 presented contains a compilation of relevant studies that address different perspectives on the use of technology and gamification in education, with a

special focus on the use of Scratch. Each entry in the table includes essential information such as the title of the study, the responsible authors, the year of publication, the priority given to the study and an associated score.

Tabela 1. Quadro teórico com os autores selecionados na fase de extração.

ID	Title	Authors	Year	Priority	Score
162360	Scratch and Sense: Using Real-Time Sensor Data to Motivate Students Learning Scratch	SURIYAARACHCHI; DENNY and NANAYAKKARA	2022	High	51
162366	Young children's social and independent behavior during play with a coding app: Digital game features matter in a 1:1 child to tablet setting	LENNON *et al.*	2022	High	19
162368	Experiences of Middle School Programming in an Online Learning Environment	ALEBAIKAN *et al.*	2022	High	15
162376	Investigating the Association between Algorithmic Thinking and Performance in Environmental Study	KANAKI *et al.*	2022	High	12
162377	Smart-thing design by children at a distance: How to engage them and make them learn	ROUMELIOTI *et al.*	2022	High	5
162383	Factors influencing younger adolescents intention to use game-based programming learning: A multigroup analysis	HU; SU and FU	2022	High	18
162384	How families design and program games: a qualitative analysis of a 4-week online in-home study	DRUGA; BALL and KO	2022	Low	16
162386	The design and evaluation of an AR-based serious game to teach programming	SHARMA *et al.*	2022	High	34
162387	Programming skills: Visualization, interaction, home language and problem solving	PRASAD; CHAUDHARY and SHARMA	2022	High	33
162389	Development and evaluation of granular simulation for integrating computational thinking into computational physics courses	MULIYATI *et al.*	2022	Low	44
162392	Coding with Block Programming Languages in Educational Robotics and Mobiles, Improve Problem Solving, Creativity & Critical Thinking Skills	MORAITI; FOTOGLOU and DRIGAS	2022	Low	21
162398	How do mathematics interest and self-efficacy influence coding interest and self-efficacy? A structural equation modeling analysis	JIANG *et al.*	2022	Low	9
162400	Keeping Fun Alive: an Experience Report on Running Online Coding Camps	FRONZA *et al.*	2022	Low	18
162403	Game-Based Learning for Young Children: A Case Study	POMBO and LAMAS	2022	High	17
162404	Educational Programming as a Strategy for the Development of Logical-Mathematical Thinking	BEDOYA and OCAÑA-GARZÓN	2022	Low	9
162406	ARcode: Programming for Youngsters Through AR	MINA; SALAH and ABDENNADHER	2022	High	19
162428	Effect of Game Elements on Game-Based Learning for Computer Programming Using Task-Technology Fit	WANG and SARI	2021	High	26
162429	A proposal of programming didactics in primary education following a gamified approach with educational videogames	GARCIA *et al.*	2021	High	24
162431	Online Learning Using Block-based Programming to Foster Computational Thinking Abilities During the COVID-19 Pandemic	AMNOUYCHOKANANT *et al.*	2021	High	44
162432	Learning about serious game design and development at the K-12 level	KAPRALOS	2021	High	34
162436	An interactive serious mobile game for supporting the learning of programming in javascript in the context of eco-friendly city management	MASKELIŪNAS *et al.*	2020	Very high	5
162438	Constructive alignment of learning mechanics and game mechanics in serious game design in higher education	KALMPOURTZIS and ROMERO	2020	High	12
162439	Can a learning companion be used to continue teaching programming to children even during the COVID-19 pandemic?	OKMAWATI	2020	Very high	40

3. Results

The study by (SURIYAARACHCHI; DENNY and NANAYAKKARA, 2022) explored integrating real-time sensors into the Scratch programming environment, simplifying coding and enhancing student motivation. The authors proposed that programs respond to physical environment changes through sensors, increasing motivation. The platform supports USB sensors for more engaging programs. (LENNON *et al.*, 2022) analyzed

children's behavior while playing coding games (Daisy the Dinosaur and Kodable) in a 1:1 setting, observing the game structure's impact and equal independence levels. Focus on learning in "Daisy the Dinosaur"improved coding understanding. (ALEBAIKAN *et al.*, 2022) investigated online programming education for elementary students in Saudi Arabia, creating an online course using Thunkable™ and TalentLMS™ to foster agency, collaboration, and digital learning benefits. (KANAKI *et al.*, 2022) studied the correlation between algorithmic thinking (AT) and performance in Environmental Education, essential for future adaptation and problem-solving, with relevance heightened by the pandemic. (ROUMELIOTI *et al.*, 2022) facilitated remote design workshops for children, emphasizing engagement, learning, and empowerment in creating technology and programming skills.

(HU; SU and FU, 2022) explored young people's perceptions of learning programming through games, investigating technology acceptance, gender, and educational level influences on learning effectiveness. (DRUGA; BALL and KO, 2022) analyzed family support's role in children's programming learning through game design using the TileCode platform, highlighting intergenerational collaboration. (SHARMA *et al.*, 2022) used Augmented Reality serious games to teach programming, showing significant progress in programming skills, particularly among less experienced players, with benefits attributed to Game Learning Analysis (GLA).

Authors (PRASAD; CHAUDHARY and SHARMA, 2022) addressed beginner challenges in programming, examining the effects of visualization, interaction, affective teaching, and native language on understanding. The application improved learning, with visualization and native language enhancing understanding and critical skills. (MULIYATI *et al.*, 2022) stressed the importance of computational thinking, integrating exercises into a physics course through the R&D method. (MORAITI; FOTOGLOU and DRIGAS, 2022) emphasized collaborative computational thinking development through educational robotics and programming, highlighting its innovative role in developing critical skills alongside traditional teaching.

Researchers (JIANG *et al.*, 2022) explore the relationship between interest and self-efficacy in mathematics and programming among high school students. (JIANG *et al.*, 2022) investigates how interest and self-efficacy in mathematics affect programming. The results indicate that interest in mathematics impacts interest in programming (JIANG *et al.*, 2022). (FRONZA *et al.*, 2022) share the experience of online programming camps during the pandemic, adapting them to maintain quality and engagement (FRONZA *et al.*, 2022). The camp guides high school students towards agile Software Engineering practices, maintaining fun and results. (POMBO and LAMAS, 2022) investigate technology adoption by children, focusing on learning programming with the Code Karts app (POMBO and LAMAS, 2022). Results demonstrate a preference for tactile devices and the advantages of gamification in learning. In the study (BEDOYA and OCAÑA-GARZÓN, 2021), the authors aim to teach children to program, developing logical-mathematical skills (BEDOYA and OCAÑA-GARZÓN, 2021). An online course engaged children in coding, resulting in notable improvements in problem-solving skills, using a block-based platform.

The researchers (MINA; SALAH and ABDENNADHER, 2022) describe a comparative study on the impact of an Augmented Reality (AR) serious game on Computer Science (CS) learning for young individuals (MINA; SALAH and ABDENNADHER, 2022). The AR game aims to teach programming concepts. The study analyzes how AR influences learning compared to the 2D version. Results may elucidate the effectiveness of AR in programming learning for the youth. In (WANG

and SARI, 2021), they examine game elements in Game-Based Learning (GBL) (WANG and SARI, 2021). Comparing two GBLs with similar game elements, they investigate variations in game elements and their impact on students' perspective. Results indicate that a combination of elements influences the perception of GBL's effectiveness and utility in programming learning. (GARCIA *et al.*, 2021) propose gamified programming education in elementary school through an educational game (GARCIA *et al.*, 2021). An experiment with 100 students aged 10 to 12 demonstrates improvements in learning and motivation. The gamified approach validates enhanced learning and student motivation. (AMNOUYCHOKANANT *et al.*, 2021) present an approach to Online Learning Using Block-Based Programming to Foster Computational Thinking Skills During the COVID-19 Pandemic (AMNOUYCHOKANANT *et al.*, 2021). The study develops online learning activities to foster computational thinking, concluding that block-based programming and pair work can potentially improve students' performance in projects during the pandemic.

The work of (KAPRALOS, 2021) highlights a gap in serious games education, especially at the K-12 level. The adoption of game design and programming education for entertainment is growing, but serious games are neglected (KAPRALOS, 2021). Lesson plans incorporate both didactic and practical components, introducing serious game concepts and careers. Remote lesson plans are feasible, even during the pandemic, and positive reception suggests the effectiveness of using serious games to engage students in programming learning (KAPRALOS, 2021). Detailed feedback from teachers and students is relevant for future research. On the other hand, the work by (MASKELIŪNAS *et al.*, 2020), authored by Rytis Maskeliūnas, Audrius Kulikajevas, Tomas Blažauskas, Robertas Damaševičius, and Jakub Swacha (2022), presents an interactive serious game for teaching programming in JavaScript (MASKELIŪNAS *et al.*, 2020). The gamified approach aims to make online education more engaging and interactive. Serious games are strategic in promoting learning, especially during the COVID-19 pandemic. Gamification increases students' interest and engagement (MASKELIŪNAS *et al.*, 2020). (KALMPOURTZIS and ROMERO, 2020) explores the design of educational games, and the authors present a constructive alignment that balances educational and game experiences, prioritizing learning outcomes. A Game-Based Learning course has a positive impact, but lacks a focus on assessment mechanisms. (OCAÑA *et al.*, 2020) addresses programming education in Primary Education, focusing on adapting for children who have already learned Scratch (OCAÑA *et al.*, 2020). The use of the Alcody environment with a learning companion improves results even during remote teaching (OCAÑA *et al.*, 2020).

4. Discussion

Articles highlight the growing importance of programming in the 21st century (LENNON *et al.*, 2022; SHARMA *et al.*, 2022; DRUGA; BALL and KO, 2022; MULIYATI *et al.*, 2022; POMBO and LAMAS, 2022). Early introduction of programming, even at preschool ages, impacts the development of computational thinking and creativity (LENNON *et al.*, 2022; SHARMA *et al.*, 2022; DRUGA; BALL and KO, 2022; MULIYATI *et al.*, 2022; POMBO and LAMAS, 2022). Block-based programming environments, such as Scratch, are effective and accessible (SURIYAARACHCHI; DENNY and NANAYAKKARA, 2022). Emerging technologies like Augmented Reality and serious games promote engagement, motivation, and problem-solving (SENDACZ; ISOTANI and LIMA, 2023). Teacher and family support, collaboration, and active participation impact motivation and learning (SOARES; FERREIRA and LIMA, 2021;

DRUGA; BALL and KO, 2022). The pandemic led to innovative online educational approaches, adapting programming activities to digital platforms (LIMA and ISOTANI, 2021; LIMA *et al.*, 2021; LIMA and ISOTANI, 2022; SENDACZ; ISOTANI and LIMA, 2023; SOARES; FERREIRA and LIMA, 2021). Challenges include diversity and equity in participation, evaluation of pedagogical and technological approaches (SHARMA *et al.*, 2022). Global use of Scratch during the pandemic highlights its potential and relevance (OCAÑA *et al.*, 2020). The evolution of programming education embraces innovative approaches and emerging technologies (OCAÑA *et al.*, 2020). Programming is a fundamental skill for 21st-century citizens (LIMA; FERREIRA and SILVA, 2021; SOARES; FERREIRA and LIMA, 2021; ROUMELIOTI *et al.*, 2022). The development of computational thinking contributes to success and skills in various areas (PRASAD; CHAUDHARY and SHARMA, 2022; MORAITI; FOTOGLOU and DRIGAS, 2022).

5. Conclusion

In conclusion, programming is essential for fostering logical thinking, problem-solving skills, and effective decision-making in an increasingly digital and interconnected world. Gamification holds a pivotal role in education, enhancing engagement and motivation, that were compromised during the pandemic, by integrating game elements into learning environments. In this context, teaching programming in a gamified way not only makes the learning process more enjoyable and engaging but also nurtures problem-solving skills and logical thinking.

Herein we analyzed works from 22 different countries, while a majority of the articles showcased positive aspects, including students' progress in programming, student agency, collaboration, and enhanced engagement and interest, some of them presented limitations. Other works, showcased the benefits of digital learning, such as, improvements in problem-solving skills, empowerment, collaboration, and motivation, especially for girls or for students with limited prior experience. Notably, a few studies highlighted a lack of focus in certain areas and a notable gap existed in focusing on assessment mechanisms to measure learning outcomes, and a couple of articles revealed a neglect of serious games, suggesting challenges in prioritizing educational value over entertainment. Future research could delve deeper into designing and implementing comprehensive assessment strategies. Besides that, a research could focus on developing strategies to bridge the gap between entertainment-focused games and educational value in serious games.

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