The use of educational robotics in the development of students' computational thinking and cognitive skills: a systematic literature review

Fernando Paula Ferreira, IFTM, ⟨fernandoferreira@iftm.edu.br⟩, 0000-0003-3314-5663
Danielli Araújo Lima, LICRo IFTM, ⟨danielli@iftm.edu.br⟩, 0000-0003-0324-6690

Abstract: Educational robotics and computational thinking can improve students' cognition by stimulating logical reasoning and creative and collaborative problem solving. In this sense, this article presents a systematic review of the literature that investigated the use of educational robotics and computational thinking in the cognitive development of students. 1080 relevant articles were identified in scientific databases and, after applying inclusion and exclusion criteria, 41 articles were selected for more detailed analysis, of which 15 were directly related to the purpose of the review. Most of the investigated studies showed a positive result, indicating that robotics and computational thinking can contribute to improving students' cognition, stimulating skills such as problem solving, logical reasoning and creativity.

Keywords: Educational robotics; Computational thinking; Cognitive development; Literature review; Problem solving; Logical reasoning.

O uso da robótica educativa no desenvolvimento do pensamento computacional e habilidades cognitivas de estudantes: uma revisão sistemática da literatura

Resumo: A robótica educativa e o pensamento computacional podem aprimorar a cognição de estudantes através do estímulo ao raciocínio lógico e resolução criativa e colaborativa de problemas. Neste sentido, este artigo apresenta uma revisão sistemática da literatura que investigou o uso da robótica educativa e do pensamento computacional no desenvolvimento cognitivo de estudantes. Foram identificados 1080 artigos relevantes em bases de dados científicas e, após a aplicação de critérios de inclusão e exclusão, foram selecionados 41 artigos para análise mais detalhada, dos quais 15 foram diretamente relacionados com o objetivo da revisão. A maioria dos estudos investigados apresentou um resultado positivo, indicando que a robótica e o pensamento computacional podem contribuir para aprimorar a cognição dos alunos, estimulando habilidades como resolução de problemas, raciocínio lógico e criatividade.

Palavras-chave: Robótica educativa; Pensamento computacional; Desenvolvimento cognitivo; Revisão da Literatura; Resolução de problemas; Raciocínio lógico.

1. Introduction

Educational robotics (ER) is an innovative approach that has been gaining ground in schools around the world. It has been used to promote interactive, creative and meaningful learning, in addition to stimulating the development of cognitive, motor and socio-emotional skills in (Carbajal e Baranauskas, 2018) students. In a context of limited resources, educational robotics becomes even more relevant, as it can be used as a low-cost teaching strategy. In addition, ER has the potential to make learning more attractive and engaging for students, especially those who have difficulties in specific areas of knowledge, making it possible to create activities that stimulate logical reasoning, problem solving, creativity and computational thinking (CT). collaboration among students (Bers; González e Torres, 2019; Khan; Francis e Davis, 2015; Kert; ErkoÇ e Yeni, 2020; Rocha *et al.*, 2021).

Currently, it is known that there are low-cost ER kits that make STEM (Science, Technology, Engineering and Mathematics) teaching more accessible for schools and students who, otherwise, would not have the resources to invest in technology cutting edge (Ince e Koc, 2021). This can contribute to reducing educational inequalities and increasing digital inclusion, in addition to preparing students for the job market of the future. ER has the potential to make teaching more attractive and practical, with the aim of improving education as a whole. Several studies have been carried out to evaluate the impacts of educational robotics on students' cognitive development (Rocha *et al.*, 2021; Rafique *et al.*, 2020; Candelas *et al.*, 2015).

This systematic literature review (SLR) aims to examine existing research on educational robotics, identifying concepts, objectives, interventions and results obtained in published studies, according to the methodology of (Kitchenham *et al.*, 2009; Kandlhofer e Steinbauer, 2016; Lima e Isotani, 2022). The review was based on three main research questions, using the StArt Tool to assist in SRL. To perform this review, six databases were used, including ACM, IEEE, Science Direct, Engineering Village, Web of Science and Scopus. The search string was defined in order to capture all the words that correlated with the main keywords related to educational robotics and cognition.

This article is organized into 5 sections with the aim of presenting an SRL on the use of RE in promoting students' cognitive development. In Section 2, we have the Research Methodology, the protocol and the article selection process are presented, followed by a discussion of the results in Section 3 Results. Section 4 deals with Lessons Learned and highlights the main insights and findings of the review and, finally, Section 5 presents the Conclusion that summarizes SRL and proposes future research directions.

2. Scientific methodology

In this work, the SRL on educational robotics 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. In our work, we use the StArt Tool application* to assist in the systematic review of the literature (Fabbri *et al.*, 2016; Sendacz; Isotani e Lima, 2022).

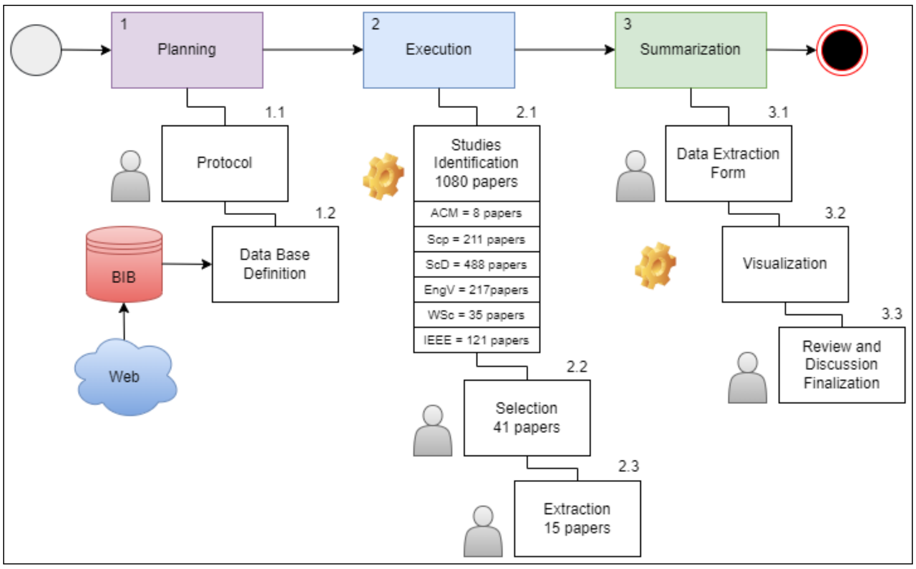


Figura 1. Process for carrying out a systematic review of the literature, the drawings of the icons of dolls represent the pieces executed manually, while the pieces with gear represent the pieces executed automatically.

*StArt (State of the Art through Systematic Review) developed by the Software Engineering Research Laboratory of the Federal University of São Carlos (UFSCAR). Access link: ⟨http://lapes.dc.ufscar.br/tools/start tool⟩.

2.1. Planing

The planning phase was divided into two main phases, the first consists of creating the research protocol manually and the second consists of extracting data automatically from the definition of the protocols. The databases (DB) are populated through the various articles found in the web cloud and serve to populate a `.bib` database, which was used in the next steps of the SLR process. In this phase, we proposed three research questions that guide the SLR process. To answer them, we first run data mining methods (i.e. data clustering approaches) and find the articles with the most similar characteristics:

Q1 What is perceived/defined as cognitive in the field of educational robotics studies?
Q2 What is the purpose and characteristics of the RE study and investigations?
Q3 What are the results in terms of cognitive development of using robotics for students?

2.1.1. Protocol

The planning phase has as a sub-step the creation of the research protocol to be used to carry out the SLR. Taking the following databases as search engines: ACM, IEEE, Science Direct, Engineering Village, Web of Science, Scopus, thus, the search string was defined "((education* OR *learn* OR teach* OR pedagog*) AND (cognit* OR brain OR neur* OR reason*) AND (robot* AND program* AND (block OR logic)))" in order to capture all the words that correlated with the main keywords (in English) from the TAK (title, abstract and keywords), considering only articles between 2012 and 2021 (last 10 years). In addition, we created a form for data extraction to facilitate the discussion of the results.

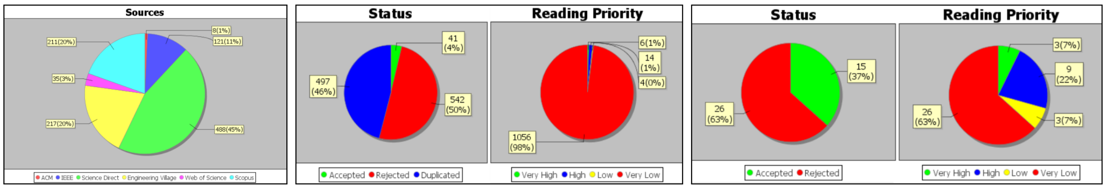
In this sense, we consider the following 12 items: (1) What are the concepts used to define educational robotics?; (2) How does educational robotics improve student performance?; (3) What is the main objective of the work?; (4) What is the working population? (if it exists); (5) What type of intervention? = [Theoretical, Practical]; (6) What is the method = [Experiment, Case Study, Survey, Other]; (7) What type of analysis was performed? = {Quantitative, qualitative, qualiquantitative, other approaches}; (8) How were data obtained? = [Experiments, Surveys, Interviews, Reports of experiences, Others]; (9) The results of the work were = {Positive, Negative, Neutral, Not reported}; (10) What is the year and country of publication?; (11) Publication type = {Journal, Conference, Book chapter}; (12) Under what circumstances was the work carried out (context)?. All questions on the survey form were answered and will be discussed in the results section.

2.1.2. Database inclusion and exclusion criteria

The scientific search for the articles was carried out in August 2021. All articles were then refined by StArt (which can be found and downloaded in the engine). In addition, in this step, the inclusion and exclusion criteria are defined. Inclusion criteria (IC) were: (IC1) article written in English or Portuguese, (IC2) peer-reviewed, (IC3) being found on StArt, (IC4) presenting guidelines for data analysis, (IC5) having been written in the last 10 years, (IC6) being a primary study. For exclusion criteria (EC) were considered: (EC1) article where robotics had no connection with education, (EC2) articles that did not involve a group of people, (EC3) articles that did not involve robotics and (EC4) articles that involved programming only.

2.2. Execution

The execution phase was divided into 3 distinct parts (see Figure 2): (i) identify the studies, (ii) select articles by reading the TAK through the evaluation of inclusion and



(a) Papers identified by DB. (b) Papers returned in Selection. (c) Papers returned in Extraction.

Figura 2. Scientific articles identified, selected and extracted in the execution phase of the SRL.

exclusion criteria. Finally, (iii) extract articles based on their complete reading. Each of these phases will be detailed in the following subsections.

2.2.1. Identification of Studies

In the studies identification phase, the six adopted databases were selected for data extraction, and a total of 1080 articles were identified. At first, a verification of duplicated articles was performed in the six databases, as shown in Figure 2(a).

2.2.2. Selection

After identifying the 1080 articles, the selection stage is performed to further refine the sorting of articles. At this stage, illustrated in Figure 2(b), 41 articles (4%) were accepted based on the inclusion criteria, 542 articles (50%) were rejected based on the exclusion criteria and 497 articles (46 %) was duplicated even though the title was different, so the duplication was manually detected. Thus, of the 41 articles selected as accepted, the reading priority was defined as follows, the 542 articles already rejected or duplicated continued with very low reading priority, as they did not pass any of the selection criteria. For the other accepted articles, a Score was created for automatic evaluation of the articles by the StArt tool. At this first moment, StArt was configured to evaluate each article with a score between $(0 - 5)$ for each time the keywords of the search string appeared in the TAK (being, $T = 5$, $A = 3$, $K = 2$ points) for each item. The reading priority for the articles appears on the right side of the Figure 2(b).

2.2.3. Extraction

The extraction step can be seen in Figure 2(c). In this case, of the 1080 articles, only 41 were selected in the previous step, serving as input for the Extraction phase. Thus, they were accepted in the extraction phase, 15 articles (37%) were extracted as accepted and (63%) were rejected in this phase. For the reading priority phase, the StArt values were configured (same as the selection step), according to Figure 2(c). In this phase of work, which consists of extracting the articles with high, very high and low priority at this stage, they were read in full, so that the summarization could be started. In this way, the fields of the data extraction form were filled out from the reading of each of the articles and saved on the StArt platform.

2.3. Summarization

In this section, we will present the summary of SRL in Educational Robotics. This step was important to summarize the main information extracted from the articles selected in the SRL and present it in a clear and objective way, using narrative analysis. The summary of the SRL in Educational Robotics included the most relevant information about the research area, such as the main skills developed by the students, the types of robots and technologies used, the school levels in which the robotics projects were applied, among other aspects. With this summary, it is possible to have an overview of the area and identify the main trends and research gaps in the field of educational robotics.

2.3.1. Completion of the review

In this section, the discussions of the 15 articles that were extracted from the SRL carried out in this master's dissertation will be presented. Based on these discussions, the questions that will be asked for high school students will be elaborated, which will be the case study investigated here.

In the work of (Carbajal e Baranauskas, 2020) the authors aimed to explore and understand the creative process of 8 Brazilian preschool children during their interaction with the tangible programming environment (`TaPrEC+mBot`) which allows the programming of a robot car through the arrangement of wooden blocks. A hands-on experiment was conducted to introduce children to computer programming using a tangible programming environment. The authors emphasized the importance of ample space to promote creative behaviors, and the dynamic relationship between the physical, digital and social dimensions favored the creative and active exploration of children. In the work of (Luna-Marín *et al.*, 2020) the authors' proposal objective (named in `Kiwcha Yachasun`, learn) relies on low-cost robotics assistants (to provide kinesthetic stimuli), an expert system (to suggest exercises and activities educational games for children) and serious games. The work was carried out with 60 children from Ecuador from low- and middle-income families during classes. A practical experiment was carried out, in which data were collected through a questionnaire applied to children aged 3 to 7 years. The proposal was highly welcomed by children and teachers, demonstrating acceptance of the project. Collecting information about users' perceptions can improve the quality and usability of the device, becoming a useful tool during the development process.

In the work of (Khamphroo *et al.*, 2017a) the authors aimed to use the robot as an educational platform and that it is suitable for students in Thailand who intend to learn to control robots with ease. The type of intervention was practical with experiment and the data were obtained with experiments. The context of carrying out the work of the system included: mobile robot and software. The authors presented as a conclusion that mobile robotics can be an excellent suitable domain for education, as it integrates mechanics, electronics, artificial intelligence, automation, informatics and mainly computer programming. In addition to the previous work, the work of (Khamphroo *et al.*, 2017b) the authors worked in the context of realization to present a prototype of an educational mobile robotic platform based on the library system `MicroPython`, which enables the control of robots with programming in language `Python`. As a conclusion, the authors indicate that robotics can be integrated with artificial intelligence for an interdisciplinary and engaging education for students.

(Sipitakiat e Nusen, 2012)'s work was to help children with robotics in Thailand, with the aim of presenting a design and analysis of debugging skills embedded in a tangible programming system called `Robo-Blocks`. Students created a program by connecting physical command blocks, which wirelessly control the movement of a floor robot. It was a hands-on intervention that used experiments to collect data. The research showed design examples of how debugging can be incorporated into a tangible programming system and concluded that this methodology is essential for engaging children in programming, helping them to understand, find and solve problems in robotics. The authors hope that the ER design experiences can be useful to others who wish to design technology to enrich the learning process for children. In the work (Rafique *et al.*, 2020) the authors aimed to improve the creativity, logical thinking and problem solving skills of children aged $4-8$. The authors used a hands-on intervention and conducted a survey of 500 public school students in Pakistan. They proposed a model that provides robotics curriculum and tools, with the aim of improving cognition of programming concepts in young people. Students were divided into five g roups a ccording t o age and were able to generate programs by sequencing instructions for their robots. It was concluded that the use of RE improves teaching and student performance, in addition to allowing the teaching of programming fundamentals and emotional intelligence without active screen time.

In the work (Lancheros-Cuesta *et al.*, 2018) the authors aimed to develop a tool based on robotics and augmented reality for developing communication skills in children in Colombia. The authors developed an educational tool, based on robotic software and augmented reality, to help students with ASD develop communication and attention skills. The tool integrates hardware and software and the authors concluded that it is effective in improving the learning and attention of children with ASD (autism spectrum disorder).In (Rocha *et al.*, 2021) the authors proposed a collaborative programming environment for visually impaired children in Portugal, using tangible blocks and auditory feedback to program a robot. They carried out a practical study online at a distance, collecting valuable feedback to enhance the education and social inclusion of these children.

In the work of (Khan; Francis e Davis, 2015) presents a project that involved elementary school teachers and children, whose objective was the assembly of motorized robots. The authors carried out the study in Canada which concluded that spatial reasoning is an important and distinct skill in relation to other conceptual competences in mathematics. They suggest that the use of dense visuospatial interfaces, such as projects, programming icons, blocks and maps, can be an interesting opportunity to apply robotics education and improve students' cognitive learning.The (Ince e Koc, 2021) study was a project in Turkey that consisted of a two-week Young Engineers Workshop (YEW) camp for 32 youth, in primary and secondary education, with the aim of stimulating interest in STEM using `Arduino` and `Scratch`. The study investigated the cognitive and affective consequences of YEW on the development of computational thinking (CT) skills. Results showed a significant increase in CT, suggesting that ER may be an effective way to promote CT to some extent, but not an adequate or complete solution.

In the (Relkin; Ruiter e Bers, 2021) work, the authors had a quasi-experimental longitudinal objective. The intervention is a version of the "Coding as Another Language (CAL) with the robot `KIBO`" curriculum to teach coding and literacy concepts to 667 children in the United States. The authors carried out a practical study with the `KIBO` robot to assess children's learning in coding using tangible blocks. The study showed cognitive improvements in children exposed to developmentally appropriate coding curriculum, including algorithms, modularity, and representation, as well as improvements in disconnected problem solving, and observed improvement in students' CT. In the work of (Kert; ErkoÇ e Yeni, 2020) the authors aimed to investigate the effect of RE on the development of 78 high school students in Turkey to investigate different groups of students who learned robotics and programming. Furthermore, the authors conducted a case study to compare the effects of RE and block-based programming environments on academic performance and perceived effectiveness of high school students' CT skills. The results showed that RE developed these skills more effectively than block-based programming environments, and that connections between concepts for students who took robotics were stronger than those who worked with block-based software.

In the work by (Candelas *et al.*, 2015) the authors presented the `Arduino` environment to students of the Automatic Control and Robotics courses at the University of Alicante in Spain and taught them how to develop a simple temperature control circuit. The type of intervention was experimental, with theoretical support, and the data were obtained in an observational way. In the end, the authors evaluated the results taking into account the students' points of view, concluding that the experiences were attractive and that the students acquired the intended knowledge about hardware configuration and programming. In the work of (Bers; González e Torres, 2019) the authors taught thinking and coding skills to children in the US using the robot `KIBO`. The cognitive framework used included sequencing, repetitions, conditionals and debugging. The work had practical intervention and evaluated an experience of ”coding as a playground”. The results confirmed that it is possible to teach new literacy skills to children as young as 3 years old, and the strategies promoted communication, collaboration and creativity in the classroom. In the work of (Gerosa Anaclara e Koleszar,) The authors compared the performance of computational thinking and cognitive skills of 183 kindergarten children in Uruguay, with practical intervention using a programmable robot. Nine cognitive tests were evaluated, such as fluid intelligence, working memory, planning and vocabulary. The results showed significant positive correlations between computational thinking performance and performance in the robotics intervention.

3. Results

This section presents a theoretical framework that aims to summarize the discussions presented in the previous section, as well as presenting data visualizations to better understand the distribution of articles around the world.

Next, we present the Table 1 that represents the Theoretical Framework that summarizes the results of the Systematic Review of the Literature in Educational Robotics. The table contains information about the 15 selected works, including the paper ID, authors, year of publication, title, order of priority, score automatically generated by the Start Tool and the educational level at which the robotics project was used with students. This information provides an overview of the analyzed studies and allows a quick comparison between them.

Finally, we will present the graphs and figures for the visualization of SRL data in Educational Robotics. The SRL analysis generated several visualizations that are essential for understanding the results and extracting important insights. These charts are essential for discussions and lessons learned to be more assertive and based on concrete data. Figure 3(a) presents the world map that shows the relationship between the countries of the authors of articles on educational robotics. It is observed that the country that most researches on the subject is Spain, with a total of 10 authors (in red in the caption), followed by Ecuador (with 7 authors), Portugal and Thailand, with 6 authors, respectively. Brazil had only 2 authors, while the Netherlands had only 1 author (in green in the legend) publishing articles on educational robotics. These data show that educational robotics is still an underexplored topic in some countries, while in others it is already widely researched and used as a pedagogical tool.

In the SRL on RE, a relationship graph was created between the 6 parameters of the data extraction form (only objective response parameters) and the 15 selected articles. Figure 3(b) shows that the parameters “Method”, “Type of Analysis”, “Type of Intervention”, “Data Collection”, “Publication Place” and “Overview”, “Result Analysis” and “Learning” are related to different articles accepted in the extraction. This visualization allows a better understanding of the relationships between the

Tabela 1. Theoretical framework that summarizes all articles selected in the systematic literature review.

ID	Title	Authors	Year	Priority	Score	Level
1	Analyzing the socioenactive dimensions of creative learning environments with preschool children	Carbajal e Baranauskas	2020	High	39	Middle School
2	An intelligent ecosystem based on robotic assistants, rule-based reasoning and serious games to support early stimulation activities for children from low-income families	Luna-Marín *et al.*	2020	Very high	66	Elementary School
3	Integrating MicroPython-based educational mobile robot with wireless network	Khamphroo *et al.*	2017	High	63	Middle School
4	MicroPython-based educational mobile robot for computer coding learning	Khamphroo *et al.*	2017	Very high	74	Middle School
5	Robo-Blocks: Designing debugging abilities in a tangible programming system for early primary school children	Sipitakiat e Nusen	2012	High	51	Elementary School
6	A Computation Model for Learning Programming and Emotional Intelligence	Rafique *et al.*	2020	High	59	Elementary School
7	Educational robotics: A teaching and learning experience in children with disorders of the autistic spectrum	Lancheros-Cuesta *et al.*	2018	High	61	Middle School
8	Fostering Collaboration with Asymmetric Roles in Accessible Programming Environments for Children with Mixed-Visual-Abilities	Rocha *et al.*	2021	Low	26	Elementary School
9	Accumulation of experience in a vast number of cases: enactivism as afit framework for the study of spatial reasoning in mathematicseducation	Khan; Francis e Davis	2015	High	38	Middle School
10	The consequences of robotics programming educa tion on computationalthinking skills: An intervention of the Young Engineer's Workshop (YEW)	Ince e Koc	2021	High	60	High School
11	Learning to code and the acquisition of compu tational thinking by young children	Relkin; Ruiter e Bers	2021	Low	16	Elementary School
12	The effect of robotics on six graders' academic achievement, computational thinking skills and conceptual knowledge levels	Kert; ErkoÇ e Yeni	2020	Very high	72	High School
13	Experiences on using Arduino for laboratory experiments of Automatic Control and Robotics	Candelas *et al.*	2015	Low	18	Undergraduated
14	Coding as a playground: Promoting positive learning experiences in childhood classrooms	Bers; González e Torres	2019	High	45	Elementary School
15	Cognitive abilities and computational thinking at age 5: Evidence for associations to sequencing and symbolic number comparison	Gerosa Anaclara e Koleszar	2021	High	40	Elementary School

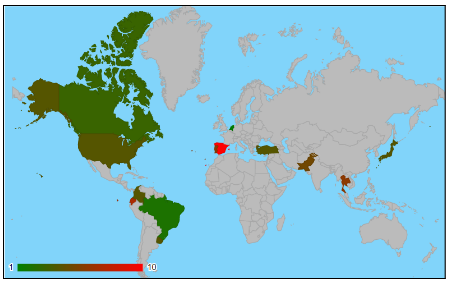
parameters and the selected publications, helping in the analysis and in the formulation of conclusions. Figure 3(c) represents the word cloud resulting from the SRL for the abstracts of the extracted publications, highlighting the words "Learning", "Robot", "System", "Control " and "Programming". In this sense, the results presented in the word cloud show that the set of keywords are related to the research.

4. Lessons Learned

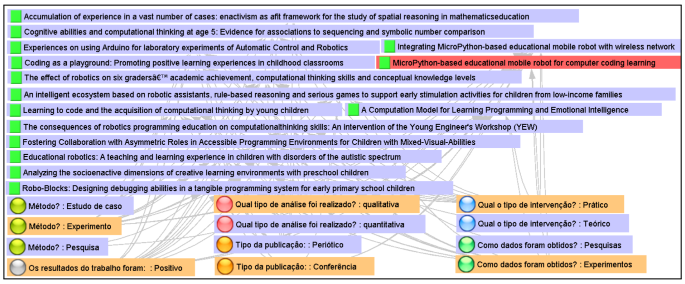
The final phase of SRL accepted 15 papers that address the use of robotics and programming as tools to aid in the learning of different skills. The authors have a common goal of using robotics and programming as teaching tools to motivate students to learn and develop important skills such as logical thinking, problem-solving, and teamwork. The studies show that robotics can contribute to the development of cognitive and creative skills in children and youth while teaching programming and automation concepts.

The authors believe that robotics can be used as a means for students to learn more advanced STEM concepts, which can be useful for their future studies and careers. They also highlight the importance of an adequate learning environment, with enough space for children to work and spread out materials. The use of games and playful activities can be an effective way to stimulate children's interest in robotics and programming.

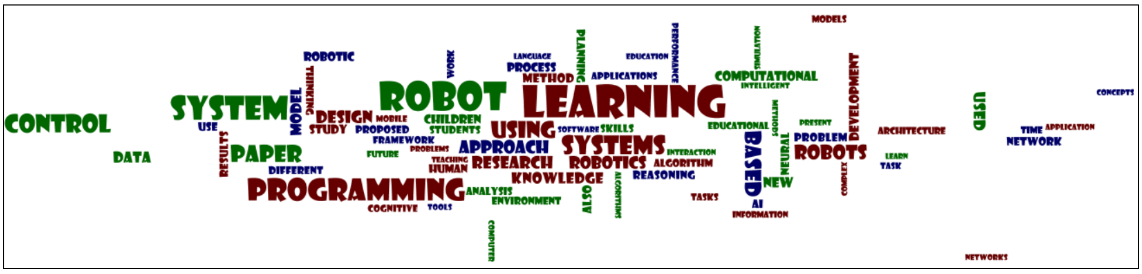
The studies presented different approaches to teaching robotics and programming, using rule-based expert systems to Python programming. For example, the authors used the Lego Mindstorms educational kit to develop software engineering skills and



(a) World map showing the distribution of authors of articles on educational robotics in SRL.



(b) Graph illustrating connections between studied attributes and articles. Attributes related to the article are highlighted in red-orange.



(c) Word cloud from the abstracts of the extracted works.

Figura 3. Summary of the data visualization generated by the StArt tool.

programming languages in university students. Another study focused on young children to understand their perceptions of adaptive robot behavior and how they learn to program it. The studies point to the relevance of robotics and programming in forming essential skills for the 21st century, such as critical thinking, problem-solving, creativity, and teamwork. The inclusion of robotics and programming in the school curriculum can be an effective way to prepare children and youth for the challenges of the modern world and promote more engaging and relevant education.

Referências

Bers, M. U.; González, C. G.; Torres, M. B. A. Coding as a playground: Promoting positive learning experiences in childhood classrooms. **Computers & Education**, Elsevier, v. 138, p. 130–145, 2019.

Candelas, F. *et al.* Experiences on using arduino for laboratory experiments of automatic control and robotics. **IFAC-PapersOnLine**, Elsevier, v. 48, n. 29, p. 105–110, 2015.

Carbajal, M.; Baranauskas, M. C. Programação, robôs e aprendizagem criativa por meio de cenários: um estudo exploratório. In: **Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)**. [S.l.: s.n.], 2018. v. 29, n. 1, p. 1113.

Carbajal, M. L.; Baranauskas, M. C. C. Analyzing the socioenactive dimensions of creative learning environments with preschool children. In: **Proceedings of the 19th Brazilian Symposium on Human Factors in Computing Systems**. [S.l.: s.n.], 2020. p. 1–10.

Fabbri, S. *et al.* Improvements in the start tool to better support the systematic review process. In: **Proceedings of the 20th international conference on evaluation and assessment in software engineering**. [S.l.: s.n.], 2016. p. 1–5.

Gerosa Anaclara e Koleszar, V. e. T. G. e. G.-S. L. e. C. A. Habilidades cognitivas e pensamento computacional aos 5 anos: Evidência de associações com sequenciamento e comparação de números simbólicos. **Computers and Education Open**, v. 2.

Ince, E. Y.; Koc, M. The consequences of robotics programming education on computational thinking skills: An intervention of the young engineer's workshop (yew). **Computer Applications in Engineering Education**, Wiley Online Library, v. 29, n. 1, p. 191–208, 2021.
Kandlhofer, M.; Steinbauer, G. Evaluating the impact of educational robotics on pupils' technical-and social-skills and science related attitudes. **Robotics and Autonomous Systems**, Elsevier, v. 75, p. 679–685, 2016.
Kert, S. B.; ErkoÇ, M. F.; Yeni, S. The effect of robotics on six graders' academic achievement, computational thinking skills and conceptual knowledge levels. **Thinking Skills and Creativity**, Elsevier, v. 38, p. 100714, 2020.
Khamphroo, M.; Kwankeo, N.; Kaemarungsi, K.; Fukawa, K. Integrating micropython-based educational mobile robot with wireless network. In: IEEE. **2017 9th International Conference on Information Technology and Electrical Engineering (ICITEE)**. [S.l.], 2017. p. 1–6.
Khamphroo, M.; Kwankeo, N.; Kaemarungsi, K.; Fukawa, K. Micropython-based educational mobile robot for computer coding learning. In: IEEE. **2017 8th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)**. [S.l.], 2017. p. 1–6.
Khan, S.; Francis, K.; Davis, B. Accumulation of experience in a vast number of cases: Enactivism as a fit framework for the study of spatial reasoning in mathematics education. **ZDM**, Springer, v. 47, p. 269–279, 2015.
Kitchenham, B. *et al.* Systematic literature reviews in software engineering–a systematic literature review. **Inf. Softw. Technol.**, Elsevier, v. 51, n. 1, p. 7–15, 2009.
Lancheros-Cuesta, D. J.; Rangel, J. E.; Rubiano, J. L.; Schlenker, C. S.; Cifuentes, J. A. Educational robotics: A teaching and learning experience in children with disorders of the autistic spectrum. In: IEEE. **2018 13th Iberian Conference on Information Systems and Technologies (CISTI)**. [S.l.], 2018. p. 1–6.
Lima, D. A.; Isotani, S. Systematic map and review of google classroom usage during the covid-19 pandemic: an analysis by data clustering approach. **Revista Brasileira de Informática na Educação**, v. 30, p. 20–49, 2022.
Luna-Marín, T. *et al.* An intelligent ecosystem based on robotic assistants, rule-based reasoning and serious games to support early stimulation activities for children from low-income families. In: IEEE. **2020 IEEE World Conference on Engineering Education (EDUNINE)**. [S.l.], 2020. p. 1–6.
Rafique, M.; Hassan, M. A.; Jaleel, A.; Khalid, H.; Bano, G. A computation model for learning programming and emotional intelligence. **IEEE Access**, IEEE, v. 8, p. 149616–149629, 2020.
Relkin, E.; Ruiter, L. E. de; Bers, M. U. Learning to code and the acquisition of computational thinking by young children. **Computers & education**, Elsevier, v. 169, p. 104222, 2021.
Rocha, F. *et al.* Fostering collaboration with asymmetric roles in accessible programming environments for children with mixed-visual-abilities. In: **Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility**. [S.l.: s.n.], 2021. p. 1–4.
Sendacz, N.; Isotani, S.; Lima, D. A. Literature review on technologies and games that motivated people to practice physical activity during the pandemic. **Revista Novas Tecnologias na Educação (RENOTE)**, v. 20, n. 2, p. 280–289, 2022.
Sipitakiat, A.; Nusen, N. Robo-blocks: designing debugging abilities in a tangible programming system for early primary school children. In: **Proceedings of the 11th Int. Conf. on Interaction Design and Children**. [S.l.: s.n.], 2012. p. 98–105.