Design Principles for Computing Education in Early Childhood

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Abstract. *This study addresses the need for clear guidelines to teach computing in early childhood, given young children's growing exposure to technology. It investigates how to design activities that integrate computational concepts while supporting holistic development. Aimed at teachers planning design processes, these principles ensure children actively collaborate in creating computing tools and that the experience remains meaningful. Derived from thematic analysis of scientific literature and validated by a focus group of computing and early education experts, five principles emerged. Findings demonstrate that linking family experiences to cooperative tasks provides educators foundation to cultivate digital literacy and computing education from the earliest school years.*

1. Introduction

Nowadays, computing is everywhere, from seeking information and entertainment to communicating with other people, working, and studying. Children of the 21st century were born into a time when technology is an integral part of our way of life, and it is almost impossible to live without it. Paiva and Costa (2015) say that "children, even before they become literate, learn to use most of the resources available on electronic devices randomly without any specific objective"; they are passive consumers of technology. A user is considered passive when they cannot create, modify, or actively participate in a solution [Fischer et al. 2004]. Although children are surrounded by technology, they do not understand the issues related to the creation or manipulation of technological products, and cannot perceive the possibilities of future uses to solve real problems.

According to the Common National Curriculum Base (BNCC) [MEC 2021], children must understand the digital world in the same way they understand the real world. It is necessary to understand aspects related to storage, processing, data transmission, ethical issues, and the social and economic impacts of technology. Children must understand the fundamental concepts of computing in a comprehensive way to understand the world around them [MEC 2021]. In the literature, there are studies involving children aged 4 and 5, and concepts of computational thinking, programming, creation of technological artifacts, or even fronts involving Design-Based Learning. However, challenges still exist, including teacher training, developing appropriate curricula, and evaluating the impact of computer science education on young children [Sentance and Csizmadia 2017].

Despite technological and methodological advances, many educators still face challenges in effectively implementing these tools and approaches in the classroom. The lack of clear guidelines adapted to the educational context makes it difficult to adopt

DOI: 10.5753/sbie.2025.12534

practices that integrate computing in a meaningful way into the early childhood education curriculum. These gaps highlight the need for research that proposes evidence-based pedagogical design principles, aiming to guide teachers in the application of computing activities that are aligned with local needs and realities.

This study aims to propose design principles for the integration of computing in early childhood education, using two complementary methodologies: Thematic Analysis and Focus Groups (FG). The thematic analysis allows the identification of relevant patterns and categories from qualitative data collected in a scientific article [Braun and Clarke 2006]. The FG composed of experts in early childhood education and computer science, serves to validate and refine the proposed principles, ensuring their applicability and relevance in the educational context [Krueger 2014]. Consequently, a collection of educational design principles was established to help teachers implement computing activities in early childhood education, fostering meaningful and contextualized learning. Additionally, the combined application of thematic analysis and FG signifies a methodological advancement in the field of educational research, providing a strong model for the development and validation of evidence-based pedagogical guidelines.

The research question guiding this study is: "What pedagogical design principles can guide the effective integration of computing education into early childhood education?". The investigation of this issue aims to contribute to the construction of a theoretical and practical framework that supports educators in adopting innovative and effective practices in teaching computing to children.

The remainder of this article is structured as follows: Section 2 presents the background and theoretical foundations. Section 3 details the methodology, including the Thematic Analysis and FG procedures. Section 4 introduces the design principles derived from the study. Section 5 discusses the implications of these principles in practice, and Section 6 concludes with final considerations and directions for future research.

2. Background

The involvement of young children in design processes has been widely studied. This type of participation acknowledges children as technology users and active collaborators in creating new solutions. While much of the research focuses on their role in designing systems, codesign with children extends beyond digital technologies and systems to encompass artifacts and physical materials. This broader perspective enables a more comprehensive examination of their creative contributions.

Children can assume different roles in design, including informants, testers, and design partners, with each role offering various levels of input and involvement [Druin 2002, de Morais et al. 2024]. Including young children in these processes benefits the participants and the resulting designs. Children gain cognitive and social skills, such as problem-solving, critical thinking, and collaboration [Van Mechelen et al. 2017]. Additionally, being recognized as a contributor boosts their self-esteem and engagement, especially when their ideas are taken seriously and implemented [Kapanen et al. 2019]. The creative input of children often leads to innovative solutions that adults might overlook [Van Mechelen et al. 2017].

Codesign with children, particularly when involving physical artifacts, expands the scope of their involvement beyond digital systems. Artifact-based design allows children to engage tactilely and imaginatively, offering opportunities to integrate their lived experiences into the design. Such approaches broaden the design landscape, allowing children's perspectives to inform diverse domains, including educational tools, play materials, and even urban spaces.

Including young children in these processes presents challenges. Designers and researchers must adapt methods to accommodate children's developmental needs, which may require additional time, resources, and careful planning [Van Mechelen et al. 2017]. Managing children's expectations about implementing their ideas is also critical, ensuring they understand that not all contributions can be realized [Kapanen et al. 2019]. However, this is a valuable practice that benefits both children and the design process outcomes. Expanding this participation to include the creation of artifacts opens new avenues for engagement and innovation. Addressing the inherent challenges thoughtfully ensures effective and meaningful collaboration, fostering skill development in children, and the significant design creation.

In the Brazilian context, this perspective is reinforced by Computing: Complement to the BNCC [MEC 2022], which establishes learning objectives for the introduction of computing concepts from early childhood education. Furthermore, several authors have emphasized the role of digital technologies in transforming educational practices. Kenski [Kenski 2003] argues that technology reshapes the dynamics of teaching and learning by creating new times and spaces for interaction. Moran [Moran 2005] highlights that the integration of technologies in education requires methodological innovation, so that the tools are not used only as support, but as mediators of meaningful experiences. Valente [Valente 1999b, Valente 1999a, Valente 2005] has long defended the idea that computing in education should go beyond technical instruction, focusing instead on problem-solving, creativity, and knowledge construction. These perspectives reinforce that, in addition to the international literature, the Brazilian field of research also recognizes computing education as a strategic element for children's development.

3. Methodology

We used two methods to propose design principles focused on computing education for 4 and 5-year-old children. Initially, a thematic analysis with 13 articles focused on computing education was carried out. Based on the highlighted themes and codes, 5 principles were proposed. Finally, we held an FG with professionals specializing in education, early childhood education, and computing areas to discuss the thematic analysis results and finalize the formalization of the principles. Two online meetings were held, each lasting 1 hour and 30 minutes.

The combined use of thematic analysis and focus groups was chosen to ensure both theoretical rigor and practical validation. Thematic analysis allowed for a systematic identification of patterns in the literature, while focus groups provided an opportunity to refine these principles through expert discussion. This methodological triangulation strengthens the validity of the results, as it integrates evidence from scientific publications with professional expertise in early childhood education and computing.

3.1. Thematic analysis

To identify and structure design principles that guide early childhood education teachers in creating activities aimed at teaching computing to children aged 4 and 5, we carried out a thematic analysis. This method is widely used in qualitative research to organize data into meaningful themes, allowing the construction of evidence-based knowledge [Braun and Clarke 2006].

3.1.1. Data Source and Data analysis

Two main sets of publications were analyzed: (I) scientific articles produced in the context of the research project "Discovering Computing", an interdisciplinary group from the Federal University of São Carlos composed of researchers from the areas of Education and Computer Science, and (II) complementary articles focused on teaching computing to children, selected based on the literature in the area. All articles analyzed in the thematic analysis can be viewed in the Appendix, Table 3 .

The selection of these data sources was based on their relevance to the research objectives and their representativeness in the field. The first set was chosen to ensure alignment with the interdisciplinary scope of the project, while the complementary articles were identified through searches in recognized academic databases (such as Scopus, ACM, and IEEE) using keywords related to "computing education in early childhood" and "participatory design with children". This ensured a broad and consistent coverage of the state of the art.

Content analysis followed the Braun and Clarke (2006) protocol and was conducted in five main stages. First, we familiarized ourselves with the material: each article was read in full to elicit initial understandings and highlight passages that mentioned methodologies, challenges, experiences, or teaching strategies. Then, in the coding phase, we assigned inductive codes to specific passages such as "meaningful learning", "use of play in computer science teaching", "collaboration in design", and "child empowerment" capturing units of meaning that reflected core practices and concepts. In the theme generation stage, we grouped related codes to structure five broad themes: (1) activities based on children's daily lives; (2) child protagonism; (3) collaborative processes; (4) intentional insertion of computing concepts; and (5) playful learning. Each grouping resulted from a joint analysis of the interrelationships between codes, ensuring that each theme reflected an aspect essential to the development of the principles.

We subsequently reviewed the themes to verify coherence and conceptual distinction, adjusting nomenclatures and eliminating overlaps. Finally, we defined and refined the five final themes together with the second author, validating their applicability to the context of early childhood education. This systematization provided the theoretical basis for formulating the design principles presented in this study.

3.1.2. Results

The thematic analysis allowed the identification of the 5 main themes that guide computing education for children in early childhood education. The 5 themes identified were: (1) Consider the child's daily life, (2) The child must be the protagonist, (3) Adopt collaborative processes, (4) Involve computer knowledge, and (5) Include playfulness. A list is available with all the codes that were grouped in the Appendix, TAble 4. Below, the identified themes are briefly explained, with their implications for the construction of design processes.

Consider the child's daily life: The analysis showed that computational concepts are favored in early childhood education when presented within the children's everyday context. This theme emerged from codes that indicated the importance of connecting computing to familiar activities and artifacts, such as the use of digital devices, remote controls, and electronic games. This approach is aligned with the Meaningful Learning Theory [Ausubel 2003], which emphasizes the importance of the relationship between new knowledge and the child's previous experiences. By incorporating elements of everyday life into computer science teaching, teachers can facilitate the construction of meanings and make learning more intuitive.

The child must be the protagonist: Another recurring aspect was the need to ensure that children are active participants in design processes. This theme emerged from codes related to active participation, children as decision-makers, and authorship in the design processes. Research on children's participatory design reinforces that children's active participation in design processes improves their relationship with technology and contributes to cognitive and socio-emotional skills development [Druin 2002].

Adopt collaborative processes: Collaboration emerged as a key element, indicating that learning occurs more effectively when children interact and share knowledge. This theme emerged from codes that highlighted the importance of group learning, communication of ideas, and collaborative solutions development. When engaged in collaborative play, children observe, imitate, or build on what they observe [Scott 2017].

Involve computer knowledge: The thematic analysis revealed the need to ensure that computational concepts are introduced in a structured and accessible manner. This theme emerged from codes that highlighted the importance of computational thinking and problem-solving in the early childhood context. According to Martins (2021), digital literacy and the introduction of computational concepts from the early school years are essential to prepare children for an increasingly technological world. In the early childhood education context, this involvement can occur through activities that explore computational concepts without the need for digital devices, such as challenges based on sequential logic and unplugged activities.

Include playfulness: The presence of play as a central learning tool was one of the most recurrent themes in the analysis of the articles. The literature emphasizes that play keeps children engaged, active in knowledge construction, and enables experimentation. This theme emerged from codes related to game use, creative exploration, and play-based learning. Children's learning occurs more effectively when mediated by play, as children demonstrate what they are learning through experimentation and spontaneous interaction with the environment [Scott 2017].

These 5 themes were essential for the construction of the design principles. Each theme reflects challenges and opportunities for computing in early childhood education, providing support for formulating applicable guidelines by teachers. The next subsection presents a second stage of research based on these findings and discusses its applicability in computing education to early childhood education.

Tabela 1. Details about FG participants.

ID	Gender	Level of education	Field of Study	Experience Time	
				Computer Science	Education
P1	F	Master degree	Education	Between 1 year and 5 years	Between 6 and 10 years
P2	F	Postdoc	Education	Less than 1 year	More than 10 years
P3	F	Postdoc	Education	Between 1 year and 5 years	More than 10 years
P4	F	Postdoc	Computer Science	More than 10 years	Between 1 year and 5 years
P5	M	Master degree	Computer Science	More than 10 years	Less than 1 year

3.2. Focal Groups

After identifying the 5 main themes through thematic analysis, an FG with experts from early childhood education and computer science areas was conducted to validate and refine the formulated design principles. The objective was to critically evaluate the principles, verifying their relevance, conceptual coherence, and applicability in the context of teaching computing to children aged 4 and 5. The methodology adopted for the FG followed approaches recommended in the literature [Krueger 2014, Braun and Clarke 2006], ensuring that the discussions were conducted in a structured and collaborative manner.

We developed a script with key questions and organized the discussion into two main stages. In the first stage, participants analyzed each principle individually, answering the following questions: (I) Is this principle relevant to computing education for this age group? and (II) Is this principle correct? In the second stage, participants evaluated the principles by answering the following questions: (I) Is there a need to exclude any formalized principles? (II) Is there a need to include any new principles? and (III) Do the principles present the minimum concepts necessary for early childhood education teachers to be able to carry out co-design processes with the objective of teaching computing to children aged 4 and 5? The answers to all questions were analyzed qualitatively, consolidating the main points raised by the experts.

3.2.1. Participants

The professionals were invited by convenience, considering their academic background and practical experience in early childhood education and computing. All participants are active in research groups and educational programs related to education or computing, ensuring a balance between expertise in pedagogy and computer science. This diversity of profiles enabled an interdisciplinary discussion, ensuring that the principles formulated were analyzed from both a pedagogical and technology design perspective.

Table 1 presents details on the participants, including gender, level of education, field of study, and time of experience. In the gender column, (F) represents the female and (M) represents the male. In the occupation column. This study obtained informed consent from all participants, who were informed about the objectives, procedures, and voluntary nature of their participation. All personal data were anonymized, and confidentiality was assured throughout the research process. The study was reviewed and approved by the Ethics Committee of Federal University of São Carlos, under protocol number 78975524.1.0000.5504.

3.2.2. Results

The FG results indicated a high degree of agreement on the principle's relevance, but suggestions for refinement were made to improve clarity and ensure their applicability in the educational context. During the meetings, participants analyzed each principle critically, pointing out conceptual and practical aspects that could be improved. Discussions ranged from terminological adjustments to the need to emphasize the teacher's role and the pedagogical intentionality of the proposed activities. Below, we present the main improvements based on the experts' contributions.

Consider the child's daily life: The relevance of this principle was widely recognized by the participants, who reinforced the need to relate computer science education to children's daily experiences. P3 highlighted that young children do not yet have a fully structured theoretical mindset, and the learning should start from what they already know. She argued that "when we think about child development, this age group works in the empirical world, as theoretical thinking is still under construction. Therefore, starting from what the child already knows is essential to enable new learning". P4 added that the principle formulation could emphasize the relationship between children, digital artifacts, and their social and natural environment. She suggested that children's everyday lives should not be understood as just their daily routine but as a set of experiences and interactions that they go through. Furthermore, participants stressed the importance of ensuring that this principle is understood as a broad approach, connecting computational concepts to contexts that are meaningful to children. No modifications to the principle statement were necessary. However, an explanation expansion was recommended to reinforce the relationship between computational learning and the child's previous experiences.

The child must be the protagonist: The term "protagonist" generated discussions among experts because it could be interpreted as a teacher's role reduction in the teaching and learning process. P3 highlighted that in early childhood education, children are often expected to act completely autonomously without structured guidance from the teacher. She argued that "the teacher will have to induce this protagonism. Children need role models, otherwise they cannot do it. This needs to be built progressively". P5 agreed, emphasizing that children's leadership development requires balancing autonomy and teacher mediation. He mentioned that, in some experiences with children, they expressed the desire to have an adult present for support, but without the adult making all the decisions. In light of these reflections, P4 suggested a reformulation of the principle title to emphasize the shared responsibility of adults in this process. She proposed using the term "stakeholders" which in computing refers to all those involved in a process. Thus, it was decided that the principle name would become "Stakeholders must build the child protagonism" ensuring that the teacher's role is recognized as essential.

Adopt collaborative processes: The principle was revised to ensure greater specificity and clarity. Participants raised concerns about the generality of the "collaborative process", which could be interpreted too broadly. P4 stressed that "what is expected is that children and adults engage in processes of joint creation. This needs to be clear so there are no misinterpretations of the term collaborative". P2 suggested replacing "processes" with "activities" to make the principle more applicable to pedagogical practice. She argued that "the word 'processes' can be very broadly interpreted. 'Collaborative activities' provide better guidance to the teacher on what should be done in the classroom". The name has been changed to "Carry out collaborative activities".

Involve computer knowledge: Participants agreed that teaching computing in early childhood education should involve broader computing concepts, not be restricted to programming. P4 suggested including the document "Computing: Complement to the BNCC" reference, which deals with the learning objectives for teaching computing in Brazilian early childhood education. She mentioned that "this document can help justify the principle and bring teachers closer to the topic, showing that computing is already recognized as an important component in early childhood education". P5 highlighted that "children already use computational concepts without realizing it. Our role is to make these concepts explicit and accessible". During the discussions, the experts agreed that "knowledge" could be replaced by "concepts" to make the principle more precise.

Include playfulness: This principle has sparked debates about differentiating playful learning from games without pedagogical mediation. P3 raised concerns that "playful" could be interpreted as an invitation to play without a structured purpose. She pointed out that "playfulness must be present but with intentionality. The activity needs to be provoking, challenging, and engaging, not just a moment of free play". P2 suggested reformulating the principle to emphasize the need for practical and thought-provoking activities, proposing that "instead of 'Include playfulness,' the principle could highlight hands-on, challenging, and thought-provoking activities". P4 agreed, highlighting that fun can be present within the context of structured learning. The name of the principle was changed to "Include Fun Activities".

4. Design principles

This study proposes a set of educational design principles aimed at supporting early childhood educators in planning and implementing computing activities through co-design processes. These principles serve as a practical guide to ensure that children aged 4 and 5, in the final stage of Early Childhood Education, can actively participate in meaningful learning experiences that foster computational thinking, creativity, and collaboration. Table 2 summarizes the five principles identified, with concise descriptions that highlight their pedagogical focus.

These principles represent a synthesis of insights from the literature and validation through expert focus groups, providing educators with clear and applicable guidelines to integrate computing into early childhood education. Importantly, they are not intended to be applied in isolation. Their combined use creates richer learning environments, balancing conceptual understanding, creativity, and collaboration. In the next section, we critically discuss the implications of applying these principles in practice, highlighting potential benefits, challenges, and conditions for successful implementation.

5. Discussion

The design principles proposed in this study provide a foundation for implementing computing education in early childhood. Rather than repeating their definitions, this section discusses their implications, potential challenges, and contributions to educational practice. The focus is on how they can support the development of computational skills, creativity, and collaboration in preschool education.

Tabela 2. Design principles for computing education in early childhood

Principle	Short description	Example of application
Consider the child's daily life	Connect computing concepts with children's everyday experiences to promote meaningful learning.	Organize a step-sequence game where children build a "recipe" (e.g., making a sandwich) to introduce algorithms.
Stakeholders must build the child protagonism	Encourage children's active participation in co-design, with teachers mediating and guiding autonomy.	Children design a maze on the floor with tape/chalk while the teacher guides peers to "program" one another through it.
Involve computer concepts	Introduce fundamental computing concepts (e.g., sequences, patterns, algorithms) as defined by Computing: Complement to the BNCC [MEC 2022].	Use rhythmic clapping games to represent loops, or sorting toys to teach classification and pattern recognition.
Carry out collaborative activities	Foster collaboration among children, teachers, and peers through structured joint tasks.	Groups create a collective story where choices follow logical "if/then" structures, simulating conditionals.
Include fun activities	Use playful and thought-provoking experiences to engage children while exploring computational ideas.	Organize a treasure hunt with logical clues that use conditionals to lead to the next step.

Consider the child's daily life: Incorporating computing concepts into everyday experiences allows children to connect new ideas with familiar contexts. This strategy strengthens meaningful learning and aligns with the Computing: Complement to the BNCC [MEC 2022]. The challenge lies in preparing teachers to identify and translate these experiences into structured learning opportunities.

Stakeholders must build the child protagonism: Children's active participation is fundamental, but it requires careful teacher mediation. Autonomy must be progressively constructed, with adults guiding interactions to ensure sustained shared thinking. The main implication is the need for teacher training focused on balancing guidance with opportunities for co-design.

Involve computer concepts: Introducing fundamental computing concepts (such as sequencing, pattern recognition, and problem-solving) helps children understand technology beyond programming. The Computing: Complement to the BNCC [MEC 2022] reinforces this approach. However, a critical challenge is ensuring that teachers feel confident with these concepts, which demands continuous professional development.

Carry out collaborative activities: Collaboration fosters social, cognitive, and emotional skills while strengthening collective knowledge construction. Activities such as group problem-solving or storytelling with logical structures illustrate this principle. The implication is that schools must provide time and space for joint creation, which is not always prioritized in curricula focused on individual outcomes.

Include fun activities: Playful and thought-provoking tasks are essential to engage young learners. Activities like treasure hunts based on logical clues or simple algorithmic games exemplify how fun can be aligned with intentional pedagogical goals. The critical issue is avoiding the reduction of play to entertainment without clear educational mediation.

Overall, these principles highlight that computing education in early childhood should not be reduced to isolated technical skills. Instead, it must integrate children's contexts, emphasize their role as active participants, and rely on structured teacher mediation. The main implication for practice is that teachers need both didactic strategies and institutional support to apply these principles effectively. Future research should explore how these principles perform in real classrooms and identify conditions that enable their successful implementation.

5.1. Limitations

This study has some limitations that must be acknowledged. First, the FG sample was small and selected by convenience, which may restrict the diversity of perspectives. Second, the proposed design principles were validated theoretically but have not yet been tested in classroom contexts with children and teachers. This represents not only a limitation but also an important avenue for future research. Conducting applied studies in real educational settings will make it possible to assess the pedagogical effectiveness and feasibility of the principles, generating empirical evidence to complement the theoretical foundation established here. Finally, the study focused on Brazilian educational guidelines, which may limit generalization to other educational systems. Future work should conduct pilot implementations and longitudinal studies to evaluate both short-term and long-term impacts of early computing education.

6. Conclusion

This study presented a set of design principles for teaching computing in early childhood education, derived from a thematic analysis of the literature and validated through a FG with experts in early childhood education and computer science. The principles offer practical guidance for educators seeking to introduce computing in a way that is both meaningful and contextually relevant.

By linking computing activities to familiar experiences, this work reinforces that children learn more effectively when concepts are introduced through materials and situations already present in their everyday lives. Valuing children as active participants proved essential, as it stimulates autonomy and supports their role as co-designers and problem solvers. Collaboration among children, teachers, and other stakeholders emerged as another cornerstone, strengthening social skills and collective knowledge construction. At the same time, deliberately integrating computing concepts such as logic, patterns, and sequences ensures that young learners develop a solid understanding that extends beyond mere programming. Ultimately, adopting playful strategies creates a dynamic and motivating environment that nurtures curiosity and experimentation.

The design principles laid out here provide a well-founded framework to support educators in cultivating computing education from the earliest school years. Continued collaboration among researchers and teachers will be crucial to developing increasingly inclusive, accessible, and effective computing education.

Referências

Ausubel, D. P. (2003). *Aquisição e retenção de conhecimentos: uma perspectiva cognitiva*, volume 1. Lisboa.

Bekker, T., Bakker, S., Douma, I., Van Der Poel, J., and Scheltenaar, K. (2015). Teaching children digital literacy through design-based learning with digital toolkits in schools. *International Journal of Child-Computer Interaction*, 5:29–38.

Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101.

de Morais, D. C. S., Falcão, T. P., and Tedesco, P. (2024). Promoting children's participation in a participatory design process in a rural school: A new role needed? *Journal of the Brazilian Computer Society*, 30(1):116–132.

De Paiva, N. M. N. and Costa, J. (2015). A influência da tecnologia na infância: desenvolvimento ou ameaça. *Psicologia. pt*, 1:1–13.

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and information technology*, 21(1):1–25.

Fischer, G., Giaccardi, E., Ye, Y., Sutcliffe, A. G., and Mehandjiev, N. (2004). Meta-design: a manifesto for end-user development. *Communications of the ACM*, 47(9):33–37.

Flood, V. J., Wang, X. C., and Sheridan, M. (2022). Embodied responsive teaching for supporting computational thinking in early childhood. In *Proceedings of the 16th International Conference of the Learning Sciences-ICLS 2022, pp. 855-862*. International Society of the Learning Sciences.

Grizioti, M. and Kynigos, C. (2021). Children as players, modders, and creators of simulation games: A design for making sense of complex real-world problems: Children as players, modders and creators of simulation games. In *Proceedings of the 20th Annual ACM Interaction Design and Children Conference*, pages 363–374.

Hai, A. A., Neris, V. P. d. A., Neris, L. d. O., and Vivaldini, K. C. T. (2020). Aprendendo e experimentando tecnologia e ciências na educação de crianças de 4 a 5 anos. pages 231–.

Hai, A. A., Neris, V. P. d. A., Neris, L. d. O., and Vivaldini, K. C. T. (2023). Descobrindo o computar: tecnologia, ciências, design e computação para crianças de 4 e 5 anos. *Cadernos CEDES*, 43(120):5–18.

Kapanen, H. et al. (2019). Children's turn to participate! educational co-design with children. *Tarbiya: revista de investigación e innovación educativa*.

Kenski, V. M. (2003). *Educação e tecnologias: o novo ritmo da informação*. Papirus editora.

Krueger, R. A. (2014). *Focus groups: A practical guide for applied research*. Sage publications.

Martins, E. C. (2021). Atividades didáticas para o ensino de computação na pré-escola.

Martins, E. C., da Silva, L. G. Z., and de Almeida Neris, V. P. (2023). Systematic mapping of computational thinking in preschool children. *International Journal of Child-Computer Interaction*, 36:100566.

MEC (2021). Base nacional comum curricular.

MEC (2022). Base nacional comum curricular - computação: Um complemento à bncc.

Menezes, S. V., de Oliveira Neris, L., Vivaldini, K. C. T., Hai, A. A., Miguel, C. C., and de Almeida Neris, V. P. (2023). Um arcabouço teórico para o ensino de computação para crianças de 4 e 5 anos pautado no codesign. In *Simpósio Brasileiro de Informática na Educação (SBIE)*, pages 948–959. SBC.

Moran, J. M. (2005). A integração das tecnologias na educação. *Salto para o Futuro*, 204:63–91.

Neris, V. A. and Hai, A. A. (2023). Tecnologia e educação: Ciências, computação (des) plugada e pensamento computacional na educação de crianças de 4 a 10 anos.

Neto, B. S. and Neris, V. (2018). Towards an interaction model for the programming of devices by children in the age of internet of things. In *Proceedings of the 17th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–5.

Neto, B. S., Neris, V., and Rodriguez, C. (2021). Building an iot programming environment with and for preschool children. In *Proceedings of the XX Brazilian Symposium on Human Factors in Computing Systems*, pages 1–11.

Scott, L. A. (2017). 21st century learning for early childhood: Guide. *Battelle for Kids*.

Sentance, S. and Csizmadia, A. (2017). Computing in the curriculum: Challenges and strategies from a teacher's perspective. *Education and Information Technologies*, 22:469–495.

Silva Neto, B., Rodriguez, C., and Neris, V. (2023). Buttons, devices, and adults: How preschool children designed an iot programming tool. *Interacting with Computers*, 35(2):301–314.

Valente, J. A. (1999a). Informática na educação no brasil: análise e contextualização histórica. *O computador na sociedade do conhecimento. Campinas: UNICAMP/NIED*, pages 1–13.

Valente, J. A. (1999b). O computador na sociedade do conhecimento. *Campinas: Unicamp/NIED*, page 75.

Valente, J. A. (2005). Pesquisa, comunicação e aprendizagem com o computador. *O papel do computador no processo ensino-aprendizagem. In: ALMEIDA, MEB*, pages 22–31.

Van Mechelen, M., Høiseth, M., Baykal, G. E., Van Doorn, F., Vasalou, A., and Schut, A. (2017). Analyzing children's contributions and experiences in co-design activities: Synthesizing productive practices. In *Proceedings of the 2017 Conference on Interaction Design and Children*, pages 769–772.

Wohl, B., Porter, B., and Clinch, S. (2015). Teaching computer science to 5-7 year-olds: An initial study with scratch, cubelets and unplugged computing. In *Proceedings of the workshop in primary and secondary computing education*, pages 55–60.

Yu, J., Hayden, R., and Roque, R. (2023). Exploring computational thinking with physical play through design. In *Proceedings of the 22nd Annual ACM Interaction Design and Children Conference*, pages 124–136.

A. All articles analyzed in the thematic analysis

Tabela 3. All articles analyzed in the thematic analysis.

Title	Authors
Discovering Computing	
Descobrindo o Computar: tecnologia, ciências, design e computação para crianças de 4 e 5 anos	[Hai et al. 2023]
Buttons, devices, and adults: how preschool children designed an IoT programming tool	[Silva Neto et al. 2023]
Tecnologia e Educação: ciências, computação (des)plugada e pensamento computacional na educação de crianças de 4 a 10 anos	[Neris and Hai 2023]
Systematic mapping of computational thinking in preschool children	[Martins et al. 2023]
Um arcabouço teórico para o ensino de computação para crianças de 4 e 5 anos pautado no codesign	[Menezes et al. 2023]
Building an IOT programming environment with and for preschool children	[Neto et al. 2021]
Aprendendo e experimentando tecnologia e ciências na educação de crianças de 4 a 5 anos	[Hai et al. 2020]
Towards an Interaction Model for the Programming of Devices by Children in the Age of Internet of Things	[Neto and Neris 2018]
Manual Search	
Exploring Computational Thinking with Physical Play through Design	[Yu et al. 2023]
Embodied responsive teaching for supporting computational thinking in early childhood	[Flood et al. 2022]
Children as players, modders, and creators of simulation games: A design for making sense of complex real-world problems	[Grizioti and Kynigos 2021]
Teaching Computer Science to 5-7 year-olds: An initial study with Scratch, Cubelets and unplugged computing	[Wohl et al. 2015]
Teaching children digital literacy through design-based learning with digital toolkits in schools	[Bekker et al. 2015]

B. Results of thematic analysis

Tabela 4. Details of the themes, their codes, and occurrences

Theme	Codes	Occurrence
Consider the child's daily life	Exploration of materials from children's everyday lives	24
	Use of technology in everyday life	10
	Need for prior knowledge	6
	Exploration of everyday situations	4
	Encouraging exploration of everyday life	4
	Encouraging the use of materials from children's everyday lives	1
The child must be the protagonist	Encouraging children's active involvement	19
	Adults as support	16
	Encouraging autonomy	6
	Children as decision makers	5
Adopt collaborative processes	Collaborative processes with children	21
	Benefits of participating in design processes	7
	Encouraging collaboration with children	2
Involve computer knowledge	Integration of multidisciplinary knowledge and computing	22
	Introduction to logic concepts	16
	Introduction to data processing concepts	10
	Introduction to prototyping concepts	10
	Encouraging the teaching of digital literacy	9
	Introduction to computational thinking concepts	8
	Introduction to electronics concepts	8
	Introduction to abstraction concepts	7
	Encouraging computer teaching	6
	Introduction to debugging concepts	6
	Encouragement of multidisciplinary teaching	5
	Introduction to data transmission concepts	5
	Benefits of teaching computing	4
	Encouraging IoT teaching	4
	Encouraging programming teaching	3
	Introduction to the concept of pattern recognition	3
	Introduction to boolean logic concepts	3
	Introduction to parallelism concepts	1
	Introduction to robotics concepts	1
Include playfulness	Encouraging play and entertainment	9
	Need to adapt the design process	3
	Integration of fun and game elements	1