
Play and Game Based Learning in Coding Education: A Bibliometric Mapping Toward Integrated Computational Thinking, Digital Literacy, and Psychomotor Outcomes in Primary Schools

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Abstract: *This study maps the thematic landscape of coding education research in primary schools through a bibliometric keyword co-occurrence analysis to clarify dominant emphases and identify underexplored directions for instructional design. Using a structured search strategy that combines coding/programming terms with play/game-based learning and learning-outcome constructs, the analysis reveals five major clusters that collectively highlight a strong concentration on computer science learning contexts (e.g., course implementation, effectiveness, engagement, and problem solving) and on experimental, digitally mediated interventions particularly digital game-based approaches aimed at improving computational thinking, motivation, and performance. Across clusters, the literature shows a consistent tendency to foreground cognitive and affective outcomes, while explicit integration of digital literacy as a comprehensive competence and psychomotor development as an equivalent educational target appears comparatively limited. The mapped themes also suggest that value-embedded and culturally grounded design principles are less frequently articulated as systematic, transferable frameworks, despite their relevance for context-sensitive learning in diverse settings. Based on these findings, the study proposes a future research agenda that moves beyond predominantly digital-game and experiment-centered trajectories by strengthening integrative outcome frameworks (computational, digital, and psychomotor domains), advancing culturally grounded design principles, and developing replicable unplugged play-based models such as the Bodhuleke Bot approach within an Educational Design Research pathway.*

Keywords: *Computational thinking, Digital literac, Psychomotor skills, Play based learning, Unplugged coding*

INTRODUCTION

Computational thinking (CT) has gained strong prominence in primary education as a transferable way of reasoning that supports problem formulation, representation, and solution design. Importantly, CT is increasingly framed as “more about thinking than computing,” foregrounding cognitive practices such as abstraction, decomposition, algorithmic reasoning, and debugging that can be developed from early schooling (Li et al., 2020). At the same time, the expansion of CT education has surfaced persistent challenges, including conceptual ambiguity, curriculum alignment, teacher readiness, equity concerns, and assessment limitations (Hooshyar et al., 2020). Within this context, coding education functions as a common instructional route to CT; however, evidence suggests that the educational value of coding extends beyond technical programming skills. For instance, coding interventions have been associated with improvements in planning and inhibitory

control, indicating potential contributions to broader cognitive and self-regulatory capacities relevant to primary learners (Videnovik et al., 2023). These insights underscore the need for developmentally appropriate designs that treat coding as an educational medium for multidimensional outcomes rather than a narrow technical endpoint.

A key debate, therefore, is not simply whether children should learn to code, but what purposes coding should serve and how those purposes should be operationalized through pedagogy. Systematic reviews have questioned whether educational programs prioritize “learning to code” versus “coding to learn,” highlighting tensions between instrumental programming instruction and broader goals such as higher-order thinking, creativity, and cross-domain learning (Popat & Starkey, 2019). This issue is particularly salient in primary grades, where students’ linguistic, cognitive, and socio-emotional characteristics vary widely and classroom constraints (time, resources, and teacher expertise) strongly shape feasible instructional choices. In response, research has increasingly explored approaches designed to make CT and coding accessible, motivating, and meaningful for young learners, including educational robotics, game-based learning, and unplugged pedagogies.

Educational robotics has attracted extensive attention because tangible programming tasks can externalize abstract computational ideas and provide immediate feedback through embodied interaction. Empirical evidence indicates that robotics interventions can support CT development and that scaffolding strategies may interact with learner characteristics (e.g., gender), implying the importance of well-calibrated instructional supports rather than generic tool adoption (Hooshyar et al., 2020). Comparative work further suggests that learning trajectories differ across modalities: robot programming and block-based play may yield distinct effects on CT-related outcomes such as sequencing and self-regulation, emphasizing that design choices about tools and activities matter (Yang et al., 2022). More recently, hybrid approaches that combine unplugged activities and educational robotics have shown promise for promoting CT and cognitive abilities in young children, suggesting that low-tech conceptual grounding and hands-on programmable artifacts can be complementary rather than competing pathways (Videnovik et al., 2023). Collectively, these trends point to a maturing research agenda that focuses less on the novelty of tools and more on how scaffolding, activity structures, and learner diversity shape learning outcomes.

In parallel, game-based learning has become a highly visible strategy for engaging children in CT practices. Classroom studies using learning games document how students develop CT through iterative problem solving, strategy

refinement, and collaboration (Asbell-Clarke et al., 2021). Meta-analytic evidence also supports positive effects of coding education programs for preschool and elementary learners, while noting that outcomes vary by program design, implementation conditions, and measurement choices (Yoo & Choi, 2023). Importantly, early coding research argues that positive learning experiences—curiosity, confidence, and willingness to experiment—are central to sustained engagement and equitable participation, especially for learners who may be discouraged by limited exposure or perceived difficulty (Bers et al., 2019). These findings highlight that affective and motivational dimensions should be explicitly designed for, not treated as incidental benefits.

Despite growth in digital game and tool-mediated interventions, a persistent practical issue remains: many schools face constraints in devices, connectivity, and technical support. For geographically remote and under-resourced contexts, “computer-based coding for all” may be an aspirational goal rather than an immediate reality. Unplugged coding therefore emerges as a critical pedagogical alternative. Research shows that computational ideas can be introduced meaningfully without computers through structured activities and physical materials that are more feasible in many classrooms (Lee & Junoh, 2019). Recent work on unplugged gamified coding tools similarly demonstrates that children can engage in coding-like reasoning and enjoy learning in intentionally non-digital designs (Huang & Wang, 2025). Such evidence challenges technology-dependent assumptions and supports unplugged approaches as an equity-oriented entry point into CT.

Coding education also intersects with literacy in ways that broaden its educational significance. The concept of computational participation positions coding as an extension of literacy instruction by expanding how learners communicate, express ideas, and participate in meaning-making with texts and media (Burke et al., 2016). Studies have shown that children produce narratives while coding, indicating cross-disciplinary pathways that connect programming with language development and multimodal composition (Price & Price-Mohr, 2018). Related work on literacy-focused computer science instruction emphasizes the role of teacher professional development and structured scaffolding to support inclusive implementation for diverse learners (Hutchison et al., 2021; Colwell et al., 2023; Hutchison et al., 2025). Together, these studies imply that a robust agenda for primary coding education should deliberately align CT learning with broader competence-oriented outcomes rather than isolating coding as a standalone subject.

Assessment research further underscores the complexity of defining and measuring learning in CT education. Reviews of CT assessment identify substantial variation in constructs, instruments, and validity evidence, indicating that outcome

claims depend on careful alignment between intervention design and measurement (Tang et al., 2020). For young learners, unplugged assessments such as TechCheck have been developed and validated, strengthening the methodological legitimacy of unplugged learning and developmentally appropriate evaluation (Relkin et al., 2020). Moreover, research examining what children learn from coding shows that outcomes extend across cognitive domains and programming knowledge, suggesting that narrow achievement indicators may overlook meaningful gains (Strawhacker & Bers, 2019; Relkin et al., 2021). These considerations reinforce the need for multidimensional outcome frameworks that reflect the breadth of learning potentially supported by coding education.

Against this background, the bibliometric analysis in the present study provides a macro-level perspective on how play-based and game-based learning in coding education has been studied and organized thematically. The keyword co-occurrence mapping identifies five dominant clusters, with strong emphases on computer science learning contexts and effectiveness/engagement, experimental digital-game-centered CT interventions linked to motivation and performance, and complementary clusters addressing development, process/outcomes, teacher/tools, and context/framework/model, alongside child interaction and group-based learning. This landscape motivates a forward-looking agenda: advancing integrative models of primary coding education that connect (1) CT as a cognitive outcome, (2) digital literacy/competence as a broader capability for responsible participation and communication, and (3) psychomotor development as a legitimate target within embodied, play-based learning designs. The inclusion of psychomotor outcomes is supported by evidence that coding interventions can influence cognitive control functions (Videnovik et al., 2020) and by the developmental logic that unplugged and tangible activities inherently involve movement, coordination, and manipulation—resources that can be intentionally leveraged rather than treated as incidental. Finally, the agenda emphasizes that context and culture should be positioned as design foundations rather than background variables, because culturally grounded learning designs can enhance meaning, identity relevance, and value-based participation structures in diverse and resource-constrained settings.

METHOD

Design

This study used a bibliometric approach to map the intellectual structure and thematic focus of research on play-based/game-based learning in coding education, emphasizing three outcome domains: computational thinking/skills, digital literacy/competence, and motor/psychomotor skills in primary learning contexts. The

workflow combined performance analysis (descriptive publication indicators) and science mapping (network visualization and clustering).

Data source and search strategy

Bibliographic records were retrieved from Scopus (search conducted in December 2025; the exact retrieval date should be reported in the final manuscript). A structured Boolean query was applied to capture (1) play/game-based learning approaches, (2) coding/programming/computational thinking terms, and (3) outcome-related keywords across computational, digital literacy, and psychomotor domains. The query used Title and Title–Abstract–Keyword fields, covering terms such as play-based learning, game-based learning, learning through play; coding, programming, computer programming, computational thinking; and outcome terms including computational skill, digital literacy, digital competence, and motor/psychomotor skill. Records were exported in CSV format including authors, title, abstract, keywords, source, year, affiliations/countries, and citation data.

Eligibility and screening

Eligibility criteria included peer-reviewed publications indexed in Scopus that (a) addressed coding/programming/CT in educational settings relevant to children/primary grades, (b) explicitly involved play-based or game-based learning, and (c) reported or discussed at least one of the targeted outcome domains. Exclusions included non-scholarly document types (e.g., editorials), records unrelated to education, metaphorical uses of “game/play” (e.g., game theory without instructional design), duplicates, and entries with insufficient bibliographic metadata. Screening proceeded in two stages: (1) title/abstract screening, and (2) full-text checking when metadata were ambiguous. Selection reporting followed PRISMA 2020 principles; a flow diagram should document retrieval, exclusions, and final corpus size.

Data cleaning and preprocessing

Prior to mapping, metadata were cleaned to improve network validity: spelling variants and synonyms were standardized (e.g., play-based vs play based; digital competence vs digital skills), plural/singular variants were harmonized, and non-informative terms were removed. A thesaurus file (if used) should be reported to ensure reproducibility.

Bibliometric analysis and visualization

Analyses were conducted in VOSviewer using keyword co-occurrence (co-word) analysis based on author keywords and indexed keywords. Full counting and association-strength normalization were applied (VOSviewer defaults for co-occurrence mapping). Clustering was performed using VOSviewer’s built-in algorithm to identify thematic groupings. Three standard outputs were generated:

Table 1. Summary of Keyword Co-Occurrence Clusters and Interpretations

Cluster	Thematic label (working interpretation)	Representative keywords (examples)	What the cluster suggests	Implications for this study
1	Computer science learning, effectiveness, and engagement	computer science; course; effectiveness; engagement; experience; problem; learner; GBL	A major stream frames playful/GBL coding primarily as <i>computer science instruction</i> and evaluates it through engagement and effectiveness indicators.	Reinforces the field’s evaluation focus and supports the need to broaden outcome frameworks beyond “effectiveness” toward multidimensional targets.
2	Design and implementation backbone	activity; development; process; outcome; teacher; tool; knowledge; education; case study	Emphasizes classroom-level design work and implementation conditions (teacher, tools, activities), indicating that pedagogy and enactment are recognized as key mediators of learning.	Supports positioning the proposed model within a design-oriented trajectory and explicitly addressing enactment feasibility in diverse contexts.
3	Context, frameworks, and sustained learning	context; environment; framework; model; evidence; data; learning; game; persistence	Highlights interest in conceptual frameworks and contextual/ecological factors, including persistence as a sustained-learning construct.	Justifies culturally grounded, context-sensitive principles and the need for a replicable framework rather than isolated interventions.
4	CT intervention studies with digital-game and experimental logic	computational thinking; digital game; experimental group; control group; motivation; performance; strategy	Signals a dominant intervention genre: digital-game-centered studies, often tested via experimental comparisons, focusing on CT gains, motivation, and performance.	Establishes CT as the dominant target outcome and motivates expanding the outcome space to include digital literacy and psychomotor domains.
5	Child-centered interaction and group programming	child; interaction; group; programming; approach; analysis; effect	Captures developmental and social dimensions of coding learning (interaction patterns, collaboration, child-appropriate approaches).	Aligns with play-based learning logics and supports designing embodied, collaborative tasks suitable for primary learners.

The cluster structure suggests that much of the field advances via an “intervention-testing” pathway: a digital game (or comparable playful environment) is designed, implemented, and evaluated using experimental or quasi-experimental

comparisons, with CT and closely related variables (motivation, performance) as central dependent measures. This orientation is consistent with synthesis evidence reporting generally positive effects of coding programs for young learners but also substantial variability tied to design and measurement decisions (Yoo & Choi, 2023; Popat & Starkey, 2019). The dominance of this trajectory is educationally productive—supporting accumulation of efficacy evidence—but it can also narrow what is treated as legitimate learning impact.

A key implication of the mapping is that digital literacy/competence and psychomotor development appear comparatively less visible as explicit, co-equal outcome targets. This matters for two reasons. First, contemporary coding education increasingly intersects with literacy and broader participation practices (Burke et al., 2016; Price & Price-Mohr, 2018), and teacher professional development models have begun to connect computer science instruction with inclusive literacy goals (Hutchison et al., 2021; Colwell et al., 2023; Hutchison et al., 2025). If coding is positioned as foundational for participation in digital environments, then outcome models should explicitly specify and measure the digital literacy dimensions expected to develop through instruction, especially because digital game-based learning is frequently discussed as a learning design that can shape broader learning experiences and learner participation beyond purely technical outcomes (Israel-Fishelson & Hershkovitz, 2020; Panskyi & Rowińska, 2021). Second, in primary classrooms—especially in unplugged and tangible-play settings—learning is often embodied. Embodied sequencing, coordination, manipulation of materials, and physically distributed collaboration are not side effects; they are structural features of the learning experience. Prior empirical findings that coding can support executive functions such as planning and inhibition (Arfé et al., 2020) and that combined unplugged–robotics training can promote CT and cognitive abilities (Arfé et al., 2023) strengthen the plausibility of designing interventions that intentionally treat psychomotor development as an aligned outcome domain rather than an incidental byproduct, particularly when game-based learning studies increasingly examine how interface and interaction design influence learner experience and engagement (Sackl et al., 2021).

The prominence of “digital game” and experimental design keywords suggests an evidence base often developed in settings where devices and infrastructure are available. Yet, implementation realities—particularly in under-resourced or remote contexts—require feasible alternatives that do not presuppose stable connectivity and device access. Unplugged coding provides a well-supported pathway for conceptual learning without computers (Lee & Junoh, 2019), and recent work indicates that unplugged gamified tools can still support children’s engagement and coding-like

reasoning (Huang & Wang, 2025). In parallel, a growing body of evidence from reviews and meta-analyses supports the conclusion that game-based learning can enhance learners' computational thinking, while also indicating that outcomes vary by design features and measurement choices (Lu et al., 2022; Ma et al., 2023; Wang et al., 2023). More recent empirical studies further show that game-based learning can strengthen CT competencies in school settings and can capture implicit CT processes in specific game designs (Pan et al., 2024; Liu, 2024), while work in primary contexts continues to model how game-based approaches can be structured to support CT development (Mohamed et al., 2024) and to align computational thinking concepts with core game-based learning elements (Yunus & Zaibon, 2021). In this light, unplugged play-based models can be interpreted not merely as methodological options, but as equity-oriented design strategies that widen access to CT learning opportunities, complementing broader digital game-based pathways that may be less feasible in constrained settings (Panskyi & Rowińska, 2021).

CONCLUSION

This bibliometric study mapped research on play-based and game-based learning in coding education and identified five dominant thematic clusters. The network shows that computational thinking (CT) is the primary learning target, most often examined through digitally mediated game interventions and evaluated using experimental or quasi-experimental designs emphasizing motivation and performance. Complementary clusters reflect attention to implementation factors (activities, tools, and teachers), contextual framing (models, frameworks, learning environments, and persistence), and child-centered interaction in programming activities. Importantly, the mapping suggests that digital literacy/competence and psychomotor development are comparatively less visible as explicit, co-equal outcome domains, despite their relevance for primary learners and the embodied nature of many unplugged/playful activities. These findings support a forward agenda that moves beyond CT-only efficacy testing toward integrative models that intentionally connect CT, digital literacy/competence, and psychomotor outcomes. Future research should operationalize multidomain outcomes with aligned measures, clarify mechanisms linking specific play/GBL features to learning gains, and develop context-sensitive, replicable instructional models—particularly unplugged approaches that strengthen feasibility and equity in resource-constrained settings.

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REFERENCES

- Asbell-Clarke, J., Rowe, E., Almeda, V., Edwards, T., Bardar, E., Gasca, S., Baker, R. S., & Scruggs, R. (2021). The development of students' computational thinking practices in elementary- and middle-school classes using the learning game, Zoombinis. *Computers in Human Behavior*, *115*, Article 106587. <https://doi.org/10.1016/j.chb.2020.106587>
- Bers, M. U., González-González, C., & Armas-Torres, M. B. (2019). Coding as a playground: Promoting positive learning experiences in childhood classrooms. *Computers & Education*, *138*, 130–145. <https://doi.org/10.1016/j.compedu.2019.04.013>
- Burke, Q., O'Byrne, W. I., & Kafai, Y. B. (2016). Computational participation: Understanding coding as an extension of literacy instruction. *Journal of Adolescent & Adult Literacy*, *59*(4), 371–375. <https://doi.org/10.1002/jaal.496>
- Colwell, J., Hutchison, A., Gutierrez, K., Offutt, J., & Evmenova, A. (2023). Elementary teachers' experiences in online professional development for literacy-focused computer science instruction for all learners. *Computer Science Education*, *34*(3), 546–565. <https://doi.org/10.1080/08993408.2023.2263831>
- Egbert, J., Shahrokni, S. A., Abobaker, R., & Borysenko, N. (2021). “It’s a chance to make mistakes”: Processes and outcomes of coding in 2nd grade classrooms. *Computers & Education*, *168*, Article 104173. <https://doi.org/10.1016/j.compedu.2021.104173>
- Hooshyar, D., Pedaste, M., Yang, Y., Malva, L., Hwang, G., Wang, M., ... & Delev, D. (2020). From gaming to computational thinking: An adaptive educational computer game-based learning approach. *Journal of Educational Computing Research*, *59*(3), 383–409. <https://doi.org/10.1177/0735633120965919>
- Huang, M., & Wang, L. (2025). Start learning coding without computers? A case study on children’s unplugged gamified coding education tool with explanatory sequential mixed method. *PLOS ONE*, *20*(9), e0330896. <https://doi.org/10.1371/journal.pone.0330896>
- Hutchison, A., Si, Q., Colwell, J., Kaya, E., Jakeway, E., Miller, B., & Evmenova, A. (2025). Scaffolding coding instruction through literacy via the Compose and Code digital platform and curriculum. *Journal of Computer Assisted Learning*, *41*(1), e13115. <https://doi.org/10.1111/jcal.13115>
- Israel-Fishelson, R., & Hershkovitz, A. (2020). Shooting for the stars. In *Learning, design, and technology* (pp. 239–258). <https://doi.org/10.4018/978-1-7998-5074-8.ch012>
- Kaplanali, U. T., & Demirkol, Z. (2017). Teaching coding to children: A methodology for kids 5+. *International Journal of Elementary Education*, *6*(4), 32–37. <https://doi.org/10.11648/j.ijeedu.20170604.11>
- Kua, M. Y., Laksana, D. N. L., Sentot, K., Marindo, A. F., & Ngongo, F. (2025). Local culture-based physics smartboard learning for problem-solving skill

- development: “Ngada” Indonesian tribe case study. *Lex Localis: Journal of Local Self-Government*, 23(S6), 5655. <https://doi.org/10.52152/srybx362>
- Laksana, D. N. L. (2020). Implementation of online learning in the pandemic Covid-19: Student perception in areas with minimum internet. *Journal of Education Technology*, 4(4), 502–509. <https://doi.org/10.23887/jet.v4i4.29314>
- Laksana, D. N. L. (2025). Schooling but not learning: Exploring the social and psychological factors affecting children’s engagement in learning. *EduBasic Journal: Jurnal Pendidikan Dasar*, 7(2), 280–293. <https://doi.org/10.17509/ebj.v7i2.88741>
- Laksana, D. N. L., Degeng, I. N. S., & Dasna, I. W. (2019). The effects of inquiry-based learning and learning styles on primary school students’ conceptual understanding in multimedia learning environment. *Journal of Baltic Science Education*, 18(1), 51–62. <https://doi.org/10.33225/jbse/19.18.51>
- Laksana, D. N. L., Qondias, D., Gunawan, K. D. H., Ayu, P. E. S., Srinadi, N. L. P., & Indrawan, I. P. O. (2025). Mapping the evolution of digital literacy in Asian learning environments: A bibliometric analysis. *Salud, Ciencia y Tecnología*, 5, 1690. <https://doi.org/10.56294/saludcyt20251690>
- Laksana, D. N. L., Qondias, D., Veliz, L., Chiu, C., Utami, K. H. D., & Listyana, I. G. A. A. P. (2025). Adapting mother tongue-based instructional models to address gender disparities in literacy and numeracy skills. *International Journal of Language Education*, 9(2), 377–391. <https://doi.org/10.26858/ijole.v1i2.75115>
- Lee, J., & Junoh, J. (2019). Implementing unplugged coding activities in early childhood classrooms. *Early Childhood Education Journal*, 47(6), 709–716. <https://doi.org/10.1007/s10643-019-00967-z>
- Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2020). Computational thinking is more about thinking than computing. *Journal for STEM Education Research*, 3(1), 1–18. <https://doi.org/10.1007/s41979-020-00030-2>
- Liu, T. (2024). Assessing implicit computational thinking in game-based learning: A logical puzzle game study. *British Journal of Educational Technology*, 55(5), 2357–2382. <https://doi.org/10.1111/bjet.13443>
- Lu, Z., Chiu, M., Cui, Y., Mao, W., & Lei, H. (2022). Effects of game-based learning on students’ computational thinking: A meta-analysis. *Journal of Educational Computing Research*, 61(1), 235–256. <https://doi.org/10.1177/07356331221100740>
- Ma, J., Zhang, Y., Zhu, Z., Zhao, S., & Wang, Q. (2023). Game-based learning for students’ computational thinking: A meta-analysis. *Journal of Educational Computing Research*, 61(7), 1430–1463. <https://doi.org/10.1177/07356331231178948>
- Mohamed, Z., Ubaidullah, N., Junus, N., Angamuthu, K., & Ahmad, A. (2024). Modelling computational thinking with game-based learning among primary school students. *International Journal of Evaluation and Research in Education*, 13(6), 4115. <https://doi.org/10.11591/ijere.v13i6.28395>
- Pan, Y., Adams, E., Ketterlin-Geller, L., Larson, E., & Clark, C. (2024). Enhancing middle school students’ computational thinking competency through game-based learning. *Educational Technology Research and Development*, 72(6), 3391–3419. <https://doi.org/10.1007/s11423-024-10400-x>

Panskyi, T., & Rowińska, Z. (2021). A holistic digital game-based learning approach to out-of-school primary programming education. *Informatics in Education*, 20(3), 461–483. <https://doi.org/10.15388/infedu.2021.12>

Popat, S., & Starkey, L. (2019). *Learning to code or coding to learn? A systematic review*. *Computers & Education*, 128, 365–376. <https://doi.org/10.1016/j.compedu.2018.10.005>

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