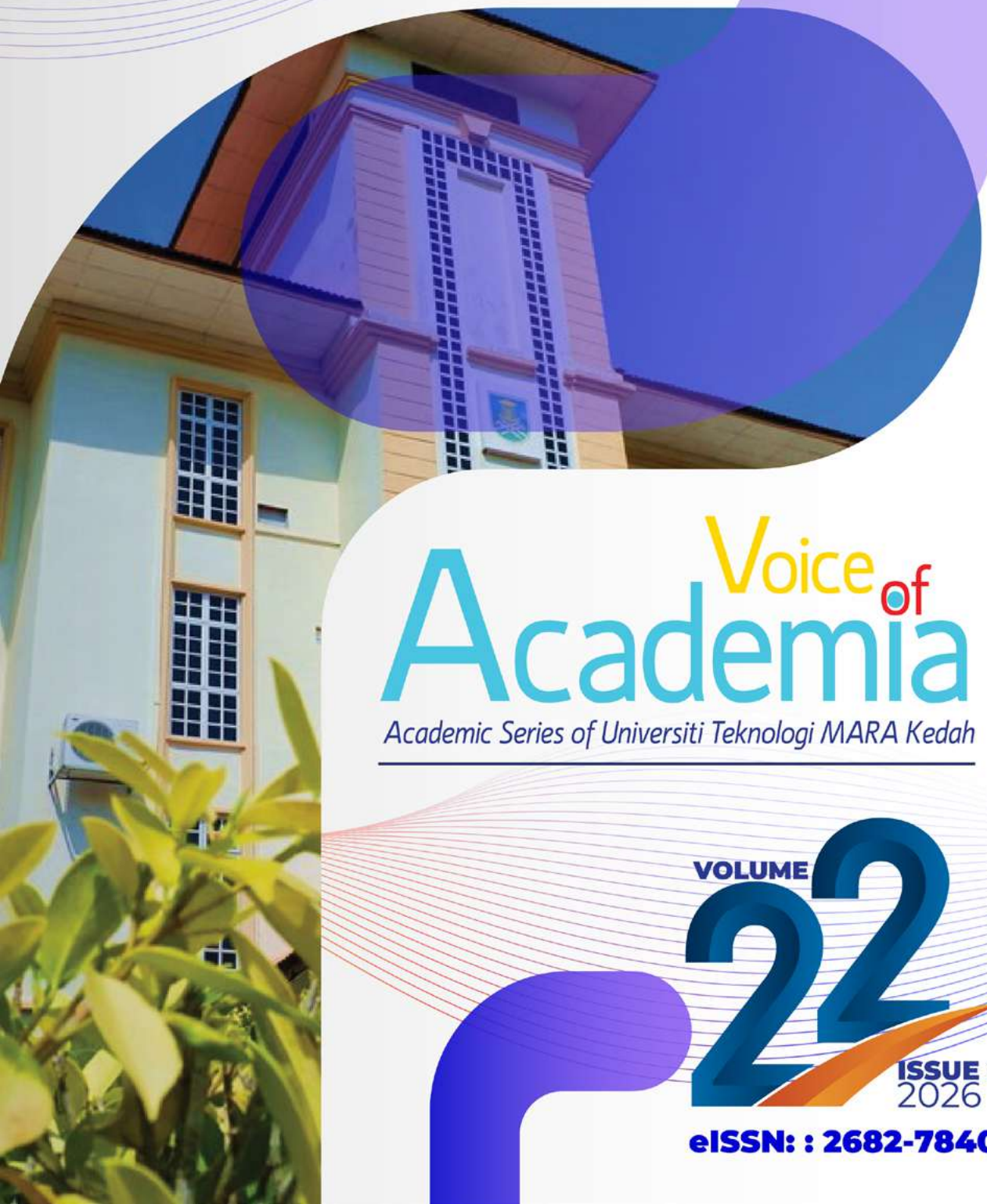

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Voice of Academia

Generative AI as a Learning Companion: Opportunities and Challenges for Novice Programmers

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ABSTRACT

Generative artificial intelligence (GenAI) is increasingly utilized to support programming education, yet its educational value for novice programmers remains uncertain because existing research is fragmented across pedagogical, technical, and ethical domains. This study aimed to synthesize current evidence on the opportunities and challenges of using GenAI as a learning companion in novice programming education and to derive implications for responsible instructional integration. A structured literature review was conducted using peer-reviewed records indexed in Scopus and published between 2023 and 2025. A Boolean search combined terms related to GenAI, learning-support functions, novice learners, and programming contexts. Scopus AI outputs, including summaries, a concept map, topic-author mapping, and emerging themes, were used as discovery and clustering aids, while the final analysis traced claims to the cited publications and compared convergent and conflicting findings. The review found that GenAI can provide personalized explanations, adaptive scaffolding, immediate feedback, coding examples, and scalable support, particularly in large classes or settings with limited instructor availability. However, the literature also identified substantial risks, including inaccurate or biased outputs, academic dishonesty, privacy concerns, unequal access, and over-reliance that may weaken debugging, problem solving, and independent reasoning. The findings therefore indicate that GenAI is most defensible as a mediated support tool rather than an autonomous tutor. Its educational value depends on explicit usage boundaries, AI literacy, source verification, transparent disclosure, and assessment designs that make student reasoning visible. The study implies that institutions should adopt pedagogy-led

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governance, provide educator development, and sequence AI support so that scaffolding can be withdrawn as competence develops. Because the review used one database and did not include classroom experiments, interviews, or control groups, future research should use multi-database, longitudinal, and controlled designs to test whether GenAI support produces durable independent programming competence.

1. INTRODUCTION

Generative Artificial Intelligence (GenAI) is changing how educational content is retrieved, produced, and used. Tools such as ChatGPT and multimodal systems can support adaptive instruction, tailored explanations, and creative learning activities (Prather et al., 2025; Hai-Jew, 2023). Programming remains a foundational but difficult area of computer science education because novice learners often struggle with abstract concepts, debugging, and sustained motivation (Rivers & Koedinger, 2013). In large classes, GenAI may supplement instructor support by providing interactive feedback, adaptive content, and tiered guidance, although these functions do not establish that learning outcomes improve without empirical evaluation (Simaremare et al., 2024; Kwak et al., 2023).

Yet GenAI use in programming education also creates pedagogical and ethical risks. Over-reliance on generated responses can reduce problem exploration and weaken opportunities to develop independent reasoning and synthesis (Simaremare et al., 2024). Human peer interaction provides empathy, participation, and co-construction of knowledge that GenAI does not reliably reproduce (Fenu et al., 2024). Accuracy, bias, and responsibility for AI-generated material can also produce unequal learning conditions (Jayaweera, 2025; Gilbert et al., 2023). Privacy and academic integrity therefore remain central concerns in higher education (Chugh et al., 2024).

Earlier research on AI in education concentrated on intelligent tutoring systems, adaptive learning environments, and AI-assisted analytics (Chrysafiadi & Virvou, 2024; Zawacki-Richter et al., 2019). That work established an important foundation but did not fully address the distinctive capabilities and risks of contemporary GenAI. Recent studies on creative programming tools such as MindScratch and GenAI-supported teaching have begun to address this gap (Chen et al., 2025; Hai-Jew, 2023; Jayaweera, 2025). However, the literature remains fragmented across technical, pedagogical, and ethical domains. A focused synthesis is therefore needed to examine how GenAI can support novice programmers without displacing the cognitive work required to learn programming.

This paper synthesizes current literature, constructs a concept map of opportunities and challenges, and examines published perspectives from prominent authors identified through Scopus AI. Its contribution is interpretive rather than experimental: it connects recurring findings, exposes tensions between support and dependence, and derives implications for responsible GenAI integration in novice programming education.

The remainder of this paper is structured as follows. Section 2 outlines the review methodology. Section 3 presents the opportunities and challenges of generative AI in novice programming education and synthesizes the findings into a concept map. Section 4 concludes with implications and recommendations for future research.

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2. METHODOLOGY

This study adopted a structured literature review supported by Scopus AI to examine the opportunities and challenges of GenAI in novice programming education. The unit of analysis was published literature, neither students nor instructors. Accordingly, the study did not administer a questionnaire, recruit interview participants, implement a classroom intervention, or assign a control group.

The search covered peer-reviewed records indexed in Scopus and published from 2023 to 2025. A Boolean query was formulated to combine four elements: GenAI, learning-support functions, novice or learner populations, and programming contexts. The query was:
("generative ai" OR "generative artificial intelligence" OR "ai" OR "artificial intelligence") AND ("learning companion" OR "learning assistant" OR "educational tool" OR "tutoring system") AND ("novice programmer" OR "beginner programmer" OR "entry-level programmer" OR "learner") AND ("programming" OR "coding" OR "software development" OR "computer programming")
Records were retained when they addressed GenAI or AI-assisted learning in programming or coding contexts and discussed novice, beginner, entry-level, or learner populations. Publications outside education or programming, unrelated to GenAI-supported learning, or insufficiently relevant to the review questions were excluded. The review considered journal articles, conference papers, and edited-volume chapters represented in the Scopus AI outputs.

Scopus AI was used to organize four output types: Summary and Expanded Summary, Concept Map, Topic Experts, and Emerging Themes. These automated outputs served as discovery, mapping, and clustering aids rather than as evidence in themselves. The authorial analysis compared the output categories, traced substantive claims to the cited publications, identified convergent and conflicting findings, and interpreted their implications for novice programming pedagogy.

The Topic Experts output was treated as author mapping, not as interview data or recruited expertise. Likewise, Emerging Themes were interpreted from publication trends and keyword relationships rather than responses from human participants. The synthesis focused on recurring opportunities, including adaptive feedback, scaffolding, accessibility, and creative support, alongside recurring risks, including inaccuracy, bias, privacy, academic integrity, and learner dependence.

Methodological transparency was supported by the explicit query, defined publication window, relevance criteria, and source-linked thematic synthesis. Because no questionnaire or experimental sample was used, questionnaire validation, reliability coefficients, sampling calculations, and control-group comparisons are not applicable. The design supports evidence synthesis and conceptual interpretation, but it cannot estimate causal effects on learning outcomes.

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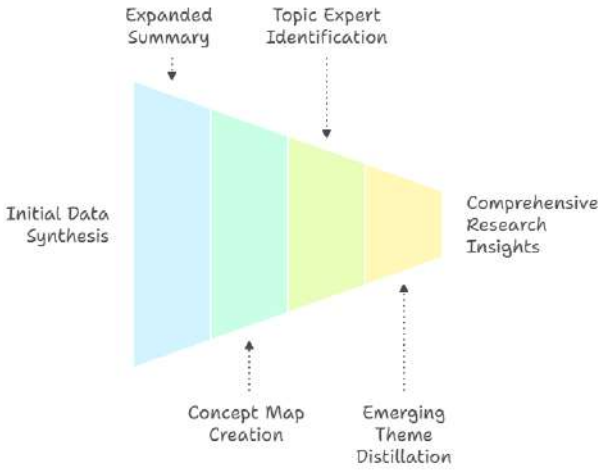

Figure 1. Four core Scopus AI output elements

3. Results and Discussion

The results of this review, derived from Scopus AI analytics and authorial interpretation of the cited literature, are presented across four dimensions: summary and expanded summary, concept map, topic-author synthesis, and emerging themes. Together, these dimensions describe the research landscape, conceptual relationships, and areas of agreement and tension in the field.

3.1 Summary & Expanded Summary

The reviewed literature reports that GenAI may support novice programmers through personalized explanations, adaptive scaffolding, and immediate feedback (Zhang & Li, 2024; Keshtkar et al., 2024). Studies also associate AI-assisted learning with self-regulation, motivation, and engagement, although the strength of evidence varies across case studies, surveys, and reviews (Hartley et al., 2024; Xiaoyu et al., 2025). Emerging pedagogical approaches include low-code or no-code environments, intelligent tutoring systems, and assessment designs that emphasize process rather than final output (Feng et al., 2025; Tolis et al., 2025). These findings indicate potential for more accessible and learner-centred programming education, but they should not be read as causal evidence from the present review (Bui et al., 2024).

However, several challenges complicate the adoption of GenAI in programming education. Over-reliance on AI-generated solutions may undermine the acquisition of fundamental programming skills, potentially leading to deskilling and demotivation among learners (Hai-Jew, 2023; Simaremare et al., 2024). Concerns over academic integrity further emerge, as students may adopt AI outputs uncritically, raising risks of plagiarism and shallow engagement with content (Chugh et al., 2024; Deng & Joshi, 2024). Equally concerning are issues of accuracy and reliability, with GenAI systems prone to hallucinations and embedded biases that novice learners may struggle to detect (Johnson, 2024; Xiaoyu et al., 2025). These challenges underscore the importance of AI literacy, metacognitive skills, and critical engagement with AI outputs, ensuring that GenAI complements rather than replaces traditional instruction (Feng et al., 2025).

Finally, implementation-related barriers such as the complexity of GenAI technologies, limited digital readiness among educators, and insufficient pedagogy-driven integration strategies remain pressing concerns (Stone, 2024; Tolis et al., 2025). Addressing these requires continuous professional development, ethical guidelines for student use, and robust institutional support to ensure responsible and effective

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adoption (Bui et al., 2024; Deng & Joshi, 2024). Overall, while GenAI offers transformative opportunities for novice programmers, its integration must be balanced, ethical, and pedagogically informed, situating it at the intersection of technological innovation, teaching practice, and academic integrity.

Table 1 compares citation counts captured in the Scopus AI output for studies published from 2023 to 2025. Hartley et al. (2024) had the highest count (43), followed by Johnson (2024) with 15, Deng and Joshi (2024) with five, and Hai-Jew (2023) with four. Zhang and Li (2024), Xiaoyu et al. (2025), and Xie and Luo (2025) had no citations in the captured output. The review-oriented studies by Chugh et al. (2024) and Stone (2024) each had two citations. Because citation counts change over time, these figures represent the Scopus AI snapshot used for this review rather than permanent measures of impact.

Table 1. Citation Impact of Key Studies on Generative AI and Novice Programming Education

Authors	Title	Year	Source title	Cited by
Zhang H.; Li M.	A Study on Impact of Junior High School Students' Programming Learning Effect Based on Generative Artificial Intelligence	2024	2024 4th International Conference on Educational Technology, ICET 2024	0
Chugh R.; Turnbull D.; Morshed A.; Sabrina F.; Azad S.; Md Mamunur R.; Kaisar S.; Subramani S.	The Promise and Pitfalls: A Literature Review of Generative Artificial Intelligence as a Learning Assistant in ICT Education	2024	Computer Applications in Engineering Education	2
Stone I.	Exploring Human-Centered Approaches in Generative AI and Introductory Programming Research: A Scoping Review	2024	ACM International Conference Proceeding Series	2
Xiaoyu W.; Zainuddin Z.; Hai Leng C.	Generative artificial intelligence in pedagogical practices: a systematic review of empirical studies (2022–2024)	2025	Cogent Education	0
Hartley K.; Hayak M.; Ko U.H.	Artificial Intelligence Supporting Independent Student Learning: An Evaluative Case Study of ChatGPT and Learning to Code	2024	Education Sciences	43
Feng T.H.; Luxton-Reilly A.; Wünsche B.C.; Denny P.	From Automation to Cognition: Redefining the Roles of Educators and Generative AI in Computing Education	2025	ACE 2025 - Proceedings of the 27th Australasian Computing Education Conference, Held in conjunction with: Australasian Computer Science Week	1
Tolis D.; Mystakidis S.; Christopoulos A.	Generative AI Applications in Education: A Low-Code/No-Code Approach	2025	Springer Series on Cultural Computing	1

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Authors	Title	Year	Source title	Cited by
Hai-Jew S.	Generative AI in teaching and learning	2023	Generative AI in Teaching and Learning	4
Keshtkar F.; Rastogi N.; Chalarca S.; Bukhari S.A.C.	AI Tutor: Student's Perceptions and Expectations of AI-Driven Tutoring Systems: A Survey-Based Investigation	2024	Proceedings of the International Florida Artificial Intelligence Research Society Conference, FLAIRS	3
Simaremare M.; Pardede C.; Tampubolon I.; Manurung P.; Simangunsong D.	Pair Programming in Programming Courses in the Era of Generative AI: Students' Perspective	2024	Proceedings - Asia-Pacific Software Engineering Conference, APSEC	0
Xie M.; Luo L.	The Impact of Generative AI on Learning Across Grades	2025	2025 14th International Conference on Educational and Information Technology, ICEIT 2025	0
Deng X.; Joshi K.D.	Promoting Ethical Use of Generative AI in Education	2024	Data Base for Advances in Information Systems	5
Johnson W.L.	How to Harness Generative AI to Accelerate Human Learning	2024	International Journal of Artificial Intelligence in Education	15
Bui N.T.A.; Nguyen L.; Nguyen N.D.K.; Hoang C.C.	Generative AI-driven Digital Transformation in Education: Systematic Review and Future Research Directions	2024	International Conference on Logistics and Industrial Engineering 2024, ICLIE 2024	0

3.2 Concept Map

The concept map produced through Scopus AI (Figure 2) offers a structured view of current research on generative tools in education. The map is organized around three clusters: pedagogical practices, challenges, and opportunities. Together, these clusters summarize the main directions in recent scholarship. The pedagogical practices cluster includes themes such as the use of tools in teaching, the development of 21st-century skills, human system interaction, and approaches to teaching programming. These themes reflect how such technologies are being integrated into instructional design and early-stage skill development. The challenges cluster draws attention to issues of online harassment and ethical concerns. These issues represent the risks of implementation and highlight the need for careful governance and responsible use in educational settings. The opportunities cluster points to areas such as personalized feedback and adaptive learning. These applications suggest potential for improving learner engagement and tailoring instruction. Taken together, the concept map presents both the risks and benefits of current approaches while outlining possible directions for future research in pedagogy, ethics, and student support.

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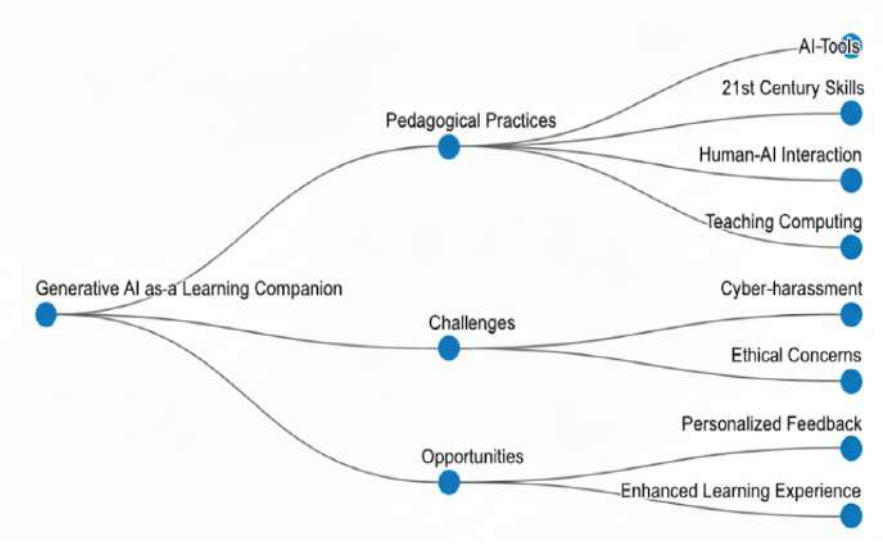

Figure 2. Concept map

3.2.1 The Relationship Between Generative AI as a Learning Companion and Novice Programmers

The reviewed literature positions GenAI as an interactive resource within programming pedagogy rather than a tool reserved for proficient learners. Reported functions include conversational explanation, feedback, content generation, and guided practice, which may help novices engage with abstract programming concepts (Blake, 2023; Jayaweera, 2025; Sandhu et al., 2024).

Studies describe individualized explanations, coding examples, and practice tasks that can supplement conventional teaching and assessment, particularly in large classes where instructor feedback is limited (Godwin-Jones, 2024; Rivers & Koedinger, 2013; Fenu et al., 2024). Tools such as MindScratch further illustrate how multimodal GenAI can support activity-based learning and computational thinking (Chen et al., 2025; Jayaweera, 2025).

The same literature identifies dependence on generated responses, reduced independent problem solving, inaccurate or biased outputs, plagiarism, and privacy risks (Simaremare et al., 2024; Watson & Shi, 2024; Nussbaum & Bekerman, 2025). GenAI is therefore better understood as a mediated learning tool than as an autonomous tutor. Its educational value depends on explicit use boundaries, AI literacy, source checking, and instructional activities that preserve learner reasoning.

3.2.1.1 The Relationship Between Generative AI as a Learning Companion and Pedagogical Practices

GenAI can support adaptive, interactive, and personalized learning pathways for novice programmers. Tools such as ChatGPT can generate explanations and feedback in response to learner prompts, which may help address individual knowledge gaps and support self-directed learning (Blake, 2023; Jayaweera, 2025; Sandhu et al., 2024). Because novices commonly struggle with syntax, debugging, and program logic, carefully designed AI assistance may reduce extraneous cognitive load while preserving the learner's responsibility to reason through the task (Godwin-Jones, 2024).

Beyond content delivery, AI assistants can facilitate dialogue, reflection, concept exploration, project ideation, and resource creation (Kharrufa & Johnson, 2024). These uses may complement established

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pedagogy and expose learners to AI-supported workflows that increasingly appear in professional practice. However, workforce relevance alone does not justify classroom adoption. Activities must still target explicit learning outcomes and develop AI literacy alongside programming knowledge (Sandhu et al., 2024).

The pedagogical value is constrained by inaccurate or biased outputs that novice learners may accept without adequate scrutiny (Watson & Shi, 2024). Over-reliance may narrow critical inquiry and reduce opportunities for productive struggle. Plagiarism, academic dishonesty, privacy, and the absence of human empathy further limit substitution of teachers or peers by AI systems (Nussbaum & Bekerman, 2025). GenAI should therefore augment, not replace, human instruction and collaborative learning.

3.2.1.2 The Challenges of Generative AI as a Learning Companion

GenAI presents both an opportunity and a challenge in novice programming education. Interactive tutoring, personalized pathways, and adaptive feedback may reduce cognitive burden, build confidence, and extend support when instructor time is limited (Jayaweera, 2025; Guettala et al., 2024). This scalability can widen access to individualized assistance, but access alone does not guarantee accurate guidance or durable learning (Bui et al., 2024).

A central risk is that GenAI can produce incorrect or misleading responses. Novices may lack the domain knowledge required to detect subtle errors, and even small programming errors can reinforce misconceptions or interrupt the development of systematic debugging and problem-solving skills (Ayari & Ouerfelli, 2025). Bias in training data and unequal access to capable systems may also reproduce existing educational disparities (Liyanage et al., 2025).

Ethical risks include plagiarism, unauthorized assistance, privacy exposure, and data security. These concerns require clear institutional policies, assessment designs that make reasoning visible, and AI literacy that teaches students to verify outputs and disclose appropriate use (Godwin-Jones, 2024).

GenAI can provide useful and engaging support, but adoption should be judged against learning objectives rather than novelty. The key design question is whether the tool strengthens independent programming competence over time or merely accelerates task completion.

3.2.1.3 The Opportunities of Generative AI as a Learning Companion

GenAI can provide contextualized explanations, individualized feedback, and timely assistance that allow novice programmers to work at an appropriate pace (Hai-Jew, 2023; Jayaweera, 2025). When used selectively, these functions may reduce avoidable cognitive burden and help learners recover from errors without waiting for instructor feedback.

Conversational AI can also support experimentation and continuous formative feedback, creating opportunities for learners to test ideas and reflect on alternative solutions (Jiang et al., 2025). These features approximate some aspects of one-to-one support, although they do not reproduce the judgment, empathy, or accountability of a human tutor.

At an institutional level, AI-based tutoring may extend learning support in settings with limited teaching resources (Chauhan et al., 2024). Educators may also use GenAI to draft examples, lesson materials, and formative activities. Any workload benefit should be balanced against the time required to verify content, protect student data, and redesign assessment (Jayaweera, 2025).

GenAI therefore offers opportunities to personalize, scale, and enrich programming education, but these benefits remain conditional. Bias, privacy, and dependence cannot be treated as secondary implementation

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issues (Lee, 2024). Ethical safeguards, transparent policies, and pedagogy that preserves independent reasoning are necessary for sustainable and equitable use.

3.3 Topic-Author Synthesis

Scopus AI identified the collective publication by Chugh et al. (2024) as a prominent source on GenAI as a learning assistant in ICT education. The paper frames GenAI as a potentially scalable and personalized support mechanism while also emphasizing misinformation, limited empathy, academic integrity, and over-reliance. Its central implication is that adoption must be guided by pedagogy rather than by technical capability alone.

Chugh, Morshed, and Subramani are coauthors of the same 2024 publication and are therefore treated collectively in this review. The manuscript no longer attributes separate 2025 publications or distinct claims to individual coauthors. This correction aligns the narrative with Table 1 and the reference list.

The collective analysis highlights a recurring tension. GenAI can widen access to explanations and scaffolding, but opaque outputs and uncritical acceptance can weaken learner autonomy. For novice programmers, transparency must include practical verification behaviours such as testing generated code, explaining program logic, comparing alternative solutions, and documenting AI assistance.

This section synthesizes published author perspectives and does not report interviews or statements from recruited experts. The term Topic Experts refers only to the author-mapping category generated by Scopus AI.

3.4 Emerging Themes

3.4.1 Consistent Themes

A consistent theme is the growing use of tools such as ChatGPT and GitHub Copilot to support coding, debugging, and project work. The literature reports faster feedback and more individualized assistance, but evidence of higher retention or durable programming competence remains limited and methodologically mixed (Hai-Jew, 2023; Jayaweera, 2025; Ayari & Ouerfelli, 2025). Over-reliance is the binding risk because efficient code completion can reduce the need to practise decomposition, tracing, debugging, and computational thinking.

Higher education literature consequently presents GenAI as a dual-use technology. It may support differentiated learning and new forms of assessment, yet it also intensifies concerns about ethics, privacy, integrity, and unequal access (Watson & Shi, 2024). Institutions need governance that defines acceptable use, disclosure requirements, data protection, and the learning processes that assessment should capture. Without these controls, productivity gains may conceal weaker independent competence (Nussbaum & Bekerman, 2025).

The consistent themes therefore concern a trade-off between immediate assistance and long-term capability development. Future research should test when AI support functions as scaffolding that can be withdrawn and when it becomes a dependency that displaces essential practice.

3.4.2 Rising Themes

Personalized learning is a rising theme in higher education research. Adaptive systems can vary explanations, pacing, and practice pathways, which may benefit novice programmers who struggle with abstract or technical material (Guettala et al., 2024; Bui et al., 2024). The unresolved question is whether

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personalization develops critical thinking and independence or simply makes continued AI use more convenient.

GenAI is also influencing instructional design. Educators can use it to draft interactive lesson plans, examples, and differentiated coding exercises (Chauhan et al., 2024). The potential benefit is rapid variation of learning materials. The corresponding risk is pedagogical oversimplification or inconsistent output, particularly when generated content is used without expert review (Lee, 2024).

A further rising theme is the use of GenAI across software engineering workflows, including code generation, design, and testing (Jiang et al., 2025). Exposure to these practices can connect classroom learning with industry contexts. However, early dependence on AI-assisted coding may prevent novices from developing program logic and independent problem-solving skills (Liyanage et al., 2025). The educational task is therefore to sequence AI use so that professional relevance does not displace foundational competence.

4. Conclusion

This structured literature review used Scopus AI to organize publications on GenAI in novice programming education and then interpreted the resulting summaries, concept map, author mapping, and themes against the cited literature. The synthesis identifies conditional opportunities in personalized explanation, immediate feedback, scalable support, and access to resources. It also identifies substantial risks involving inaccurate outputs, academic integrity, privacy, bias, and dependence. No questionnaires, interviews, expert participants, classroom intervention, or control group formed part of the study, so the findings support conceptual synthesis rather than causal claims about learner improvement. The review is limited by its reliance on one indexed database, the opacity of Scopus AI ranking and clustering, the absence of primary classroom evidence, and the lack of a preregistered multi-database screening flow. Future studies should report full search and screening counts, compare databases, and use controlled or longitudinal designs to test whether AI-supported scaffolding produces independent programming competence after support is withdrawn.

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