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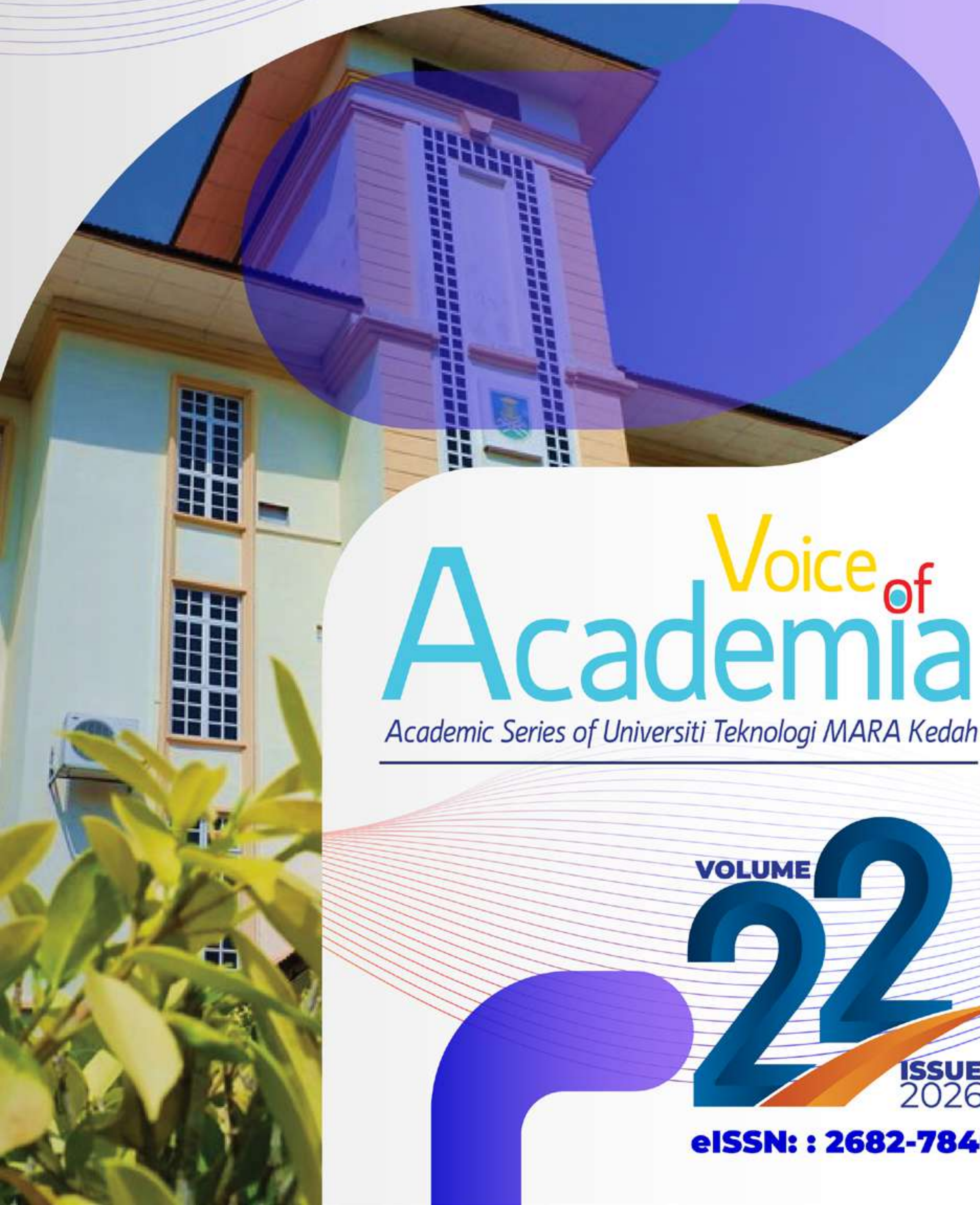

Voice of Academia

Academic Series of Universiti Teknologi MARA Kedah

VOLUME 22

ISSUE 2

2026

eISSN: : 2682-7840

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e-ISSN:2682-7840

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Available online at
https://voa.uitm.edu.my/v1/
https://journal.uitm.edu.my/index.php/VOA/issue/archive

e-ISSN: 2682-7840

Voice of Academia 22(2) 2026, Ahmad et al.

Voice of Academia

Digital Amnesia in The Digital Classroom: A Review of Memory Retention Challenges Among Computer Science Students

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ARTICLE INFO

Article history:

Received Sept 2025
Accepted June 2026
Published July2026

Keywords:

Digital Amnesia
Memory Retention
Computer Science Education
Digital Competencies
Personalized Learning

Corresponding Author:
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DOI:
https://doi.org/10.24191/VoA.v22i1.13446

ABSTRACT

Digital learning environments expose computer science students to repositories, coding platforms, automated assessment, and AI tools that may encourage cognitive offloading and weaken durable learning. This scoping evidence-mapping review examined how digital amnesia affects retention in computer science education and identified pedagogical responses. Guided by PRISMA-ScR and PRISMA-S, the review used Scopus AI to analyze expanded summaries, concept maps, topic experts, and emerging themes, with claims checked against Scopus records. Findings link digital amnesia to unregulated tool use, information overload, limited retrieval practice, emotional strain, and unequal access rather than technology itself. Effective responses include spaced retrieval, interleaving, spiral sequencing, retrieval-first activities, delayed hints, and controlled tool use. AI-supported personalization may adapt practice and feedback. Future research should test these approaches through longitudinal, cross-cultural studies using delayed-retention and knowledge-transfer measures.

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1. INTRODUCTION

Digital devices have become central to learning, communication, and information storage. However, heavy dependence upon such devices may contribute to digital amnesia, a tendency to forget information that individuals expect to retrieve from external digital sources. This phenomenon raises

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concerns about long-term memory retention and cognitive development. The issue is particularly relevant in higher education, including computer science programmes that make extensive use of coding platforms, automated assessment systems, online repositories, and AI-supported learning resources (Skulmowski & Xu, 2022).

Computer science students face distinct challenges because their studies involve abstract concepts that require both memorization and application. Overdependence on digital resources often results in cognitive offloading, storing knowledge externally instead of in long-term memory (Risko & Gilbert, 2016). This leads to only surface-level understanding, where students remember where information is stored but not the content, limiting comprehension and knowledge transfer (Sparrow et al., 2011). Information overload adds to the problem by overwhelming working memory, increasing fatigue, and reducing the ability to filter and prioritize information (Bawden & Robinson, 2020; Jiang et al., 2021). The digital divide further reinforces inequalities in access and learning outcomes (van Dijk, 2020).

Studies show several ways to address this problem. Retrieval techniques such as spaced practice and interleaved quizzes can help improve students' memory (Roediger & Karpicke, 2006; Cepeda et al., 2008). In addition, moderate and controlled use of digital tools is important so that students can think independently and solve problems (Skulmowski & Xu, 2022). Furthermore, managing emotions such as anxiety and lack of interest can also help in knowledge retention (Junco, 2012).

Despite increasing concern about technology-related memory effects, the literature remains fragmented across cognitive psychology, educational technology, digital literacy, and computer science education. This gap partly exists because coding platforms, generative AI tools, automated assessment systems, and online information resources have developed more rapidly than longitudinal pedagogical research on their effects. Existing studies also employ related but inconsistent terms, including digital amnesia, cognitive offloading, information overload, and technology dependence. Consequently, evidence directly examine how these processes affect the retention and transfer of computer science knowledge remains limited. Many computer science education studies concentrate on course persistence, engagement, or academic performance without explicitly investigating memory mechanisms. This review addresses the gap by mapping the available evidence, identifying relationships among the principal cognitive and educational constructs, and synthesizing pedagogical strategies that may support durable learning among computer science students.

2. Methodology

This review used a scoping evidence-mapping approach to clarify key concepts, outline the field, and identify knowledge gaps. It followed PRISMA-ScR and PRISMA-S reporting guidelines (Arksey & O'Malley, 2005; Tricco et al., 2018; Rethlefsen et al., 2021). The research on "digital amnesia" in computing education was analyzed using Scopus AI during a set trial window (3–18 March 2025). Scopus AI was selected for its integration with Scopus' peer-reviewed database and its ability to generate structured outputs, including summaries, syntheses, concept maps, expert identification, and emerging themes, supported by source trails and reproducible calculations (Elsevier, 2024a; Elsevier, 2024b; Sacred Heart University Library, 2025; Elsevier LibGuides, 2025; Scopus Blog, 2024).

2.1 Search strategy and query optimization

A standard search was carried out daily during the trial period using the following Boolean string (entered directly into the Scopus AI prompt box and recorded in the search diary):

("digital amnesia" OR "memory loss" OR "information overload" OR "cognitive offloading") AND ("education" OR "learning" OR "teaching" OR "academic") AND ("technology" OR "digital tools" OR "online resources" OR "e-learning") AND ("impact" OR "effect" OR "consequence" OR "influence") AND ("student" OR "learner" OR "pupil" OR "educator").

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Scopus AI broke down and refined the search while showing the optimization steps and reference sources used. The results were exported or screen-captured for audit purposes (Elsevier, 2025). To avoid bias from daily updates, the search was repeated on 3, 10, and 18 March. Minor record differences were reconciled according to PRISMA-S guidelines (Rethlefsen et al., 2021).

2.2 Data sources, eligibility, and selection

The main records were taken from Scopus-indexed journals, conference proceedings, and reviews. The selected sources had to be: (i) peer-reviewed; (ii) written in English; (iii) related to memory or retention issues connected to the use of digital tools in education, such as cognitive offloading and information overload; and (iv) conceptual, empirical, or review studies relevant to computer science education. Non-academic works, duplicates, and studies not clearly related to learning or retention, such as clinical amnesia which is unrelated to education, were excluded. After each search, Scopus records were checked to verify bibliographic information and remove duplicates before mapping (Elsevier, 2024a).

2.3 Use of Scopus AI analytics

As illustrated in Figure 2.1, Scopus AI outputs were systematically analyzed across four modules:

1. Summary & Expanded summary. These provided topic overviews and structured subtopics with citations. Extracted elements included definitions of digital amnesia/cognitive offloading, retention mechanisms, and educational impacts in computing. Confidence indicators and "foundational documents" were cross-checked against Scopus records, retaining only verifiable claims (Elsevier, 2024a; 2024b).
2. Concept map. Exported nodes and edges visualizing relationships among subtopics for example cognitive offloading → retrieval practice; information overload → cognitive load, were translated into a provisional conceptual framework. Synonyms and overlapping clusters were normalized before integration (Elsevier, 2024c; UIndy Library, 2024).
3. Topic experts. Lists of frequently publishing authors were captured and validated using Scopus author profiles for example, h-index, recent work. Only experts consistently appearing across runs were retained to address volatility in LLM-assisted rankings (Elsevier, 2024a; Creighton University Libraries, 2025; Choice, 2025).
4. Emerging themes. The algorithmic detection of established, rising, and novel themes over the past two years provided insights into retrieval-based learning, balanced tool use, and AI-assisted study behaviors. Representative papers were checked against Scopus records, and overlapping clusters were consolidated. Novel themes were cautiously interpreted, following Elsevier's guidance on reproducibility (Scopus Blog, 2024; Elsevier LibGuides, 2025; Sacred Heart University Library, 2025).

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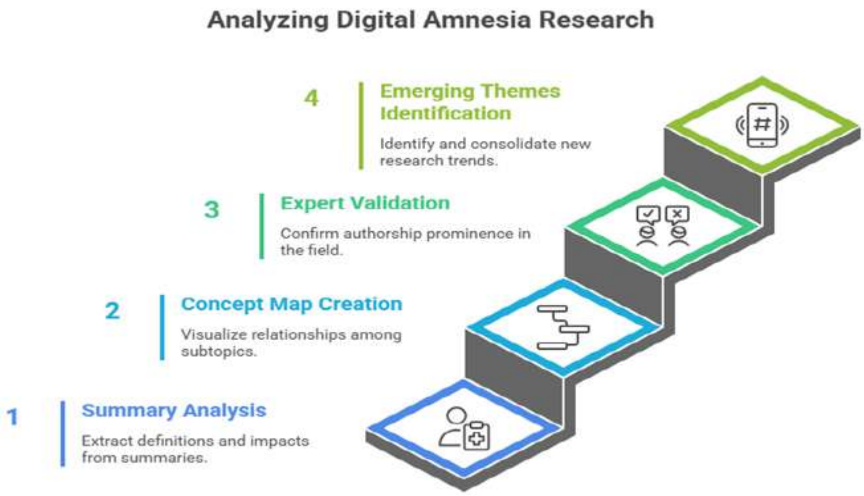

Figure 2.1 : Analyzing Digital Amnesia Research

2.4 Charting, synthesis, and quality safeguards

Following scoping-review conventions, a charting template was used to extract study type, educational level, computer science subdomain for example, programming and algorithms, memory constructs such as retention, offloading, and overload, interventions, outcomes, and implications. Three evidence streams; Expanded summaries, Concept-map clusters, and Emerging themes, were triangulated to construct an integrated conceptual framework of digital amnesia in the digital classroom. To minimize Large Language Model (LLM) influence, all statements in the narrative synthesis were grounded in verifiable Scopus records. Inconsistencies in coding were addressed by re-examining the source documents and giving priority to studies with more robust methodological reporting.

2.5 Alignment with study aims

This methodological pipeline was designed to directly support the study's objectives: (i) mapping the research landscape through Scopus AI analytics; (ii) articulating a conceptual framework for computer science education by translating Concept maps into a domain-specific model; (iii) identifying leading topic experts through validated profiles; and (iv) highlighting consistent, rising, and novel themes to guide future inquiry (Elsevier, 2024a; 2024b; 2024c; Scopus Blog, 2024).

3. Results and Discussion

This section presents the key findings derived from Scopus AI Analytics, structured around four core elements: (i) Summary & Expanded Summary, (ii) Concept Map, (iii) Topic Experts, and (iv) Emerging Themes. Drawing on Scopus AI's evidence base, digital amnesia in computer science education is framed as a systemic consequence of routine cognitive offloading to digital tools and pervasive information overload. Together, these factors raise extraneous cognitive load and shift learners' memory orientation from content retention toward "where-to-find-it" knowledge (Sparrow et al., 2011; Risko & Gilbert, 2016; Skulmowski & Xu, 2022). The Concept Map illustrates more clearly how antecedents, such as offloading, cognitive overload, and unequal access, are connected to pedagogical strategies like retrieval

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practice, spaced repetition, interleaving, and spiral sequencing. These strategies help students remember over the long term and reuse knowledge, showing that well-planned teaching methods can strengthen memory and understanding (Roediger & Karpicke, 2006; Cepeda et al., 2008; Rohrer, 2012; Lionelle & Davis, 2022). Topic experts and emerging themes suggest practical steps such as including frequent but simple retrieval activities in labs and exams, regulating how students use tools with retrieval-focused workflows, for example, giving delayed hints or searching at later stages, and reducing emotional pressures like anxiety or overload that may disrupt the use of strategies. In short, solutions to digital amnesia rely more on instructional design rather than solely on tool use. Future studies should test a combination of methods such as retrieval-first, spiral sequencing, and controlled tool use, by evaluating how well students can remember and apply knowledge within Computer Science curricula. (Bawden & Robinson, 2020; Roediger & Karpicke, 2006; Skulmowski & Xu, 2022).

3.1 Summary & Expanded Summary

The Summary and Expanded Summary touch on a clear explanatory cluster: digital amnesia in higher education arises from the interaction of (a) routine cognitive offloading to digital devices, (b) pervasive information overload in online learning environments, and (c) unequal access to digital infrastructure. Skulmowski's (2023) conceptual work on digital externalization foregrounds how learners increasingly encode where information is found rather than the information itself, leading to weaker content retention and lower understanding. This effect is especially problematic when students must transfer conceptual knowledge to different programming problems. Complementary empirical and conference literature shows that a condition in which the overflow of online teaching and learning materials increases unnecessary cognitive load, causes emotional exhaustion, and weakens students' ability to filter and prioritize essential knowledge (Khrapov & Baeva, 2022; Petrasuc & Popescul, 2019; Frolova et al., 2020). In computer science, students are good at finding answers quickly using tools like APIs, forums, or AI, but they often struggle to really understand algorithms, debugging methods, and key concepts needed for solving new problems.

The Expanded Summary emphasizes that access inequalities shape vulnerability to digital amnesia. According to Hsu and Mimura (2017), the "secondary digital gap" means students with limited device access or unstable connectivity lose valuable practice opportunities and miss out on memory-supportive instructional designs available in digital platforms. This situation further widens the gap in learning retention and achievement among student groups. Equity is essential because relying only on online flashcards, adaptive systems, or frequent auto-graded activities may disadvantage under-resourced learners unless institutions also provide access and tailored support.

On the intervention side, the Expanded Summary reveals strong evidence supporting spaced retrieval, interleaving, and retrieval-first sequencing as strategies for strengthening long-term retention in STEM and computing education. Conference reports demonstrate measurable benefits when low stakes distributed quizzes and interleaved problem sets are embedded systematically in programming courses, improvements include better delayed recall and transfer to subsequent coursework (Yasar et al., 2019; Moraes & Folkestad, 2024). Importantly, these techniques are positioned as instructional design strategies rather than outright restrictions on tool usage. The best way to prevent forgetfulness is by combining retrieval practice with controlled use of tools, such as prediction-before-reveal tasks, "search-last" phases, and delayed hints within automated grading systems. Such an approach can preserve authenticity while at the same time promoting appropriate cognitive processing. (Sanchez-Ruiz et al., 2024).

The summary also emphasizes that too much information and the rapid pace of digital learning can increase anxiety, feelings of isolation, and emotional exhaustion among students. This will cause students to use fewer effective study strategies and make it harder for them to remember what they have learned (Khrapov & Baeva, 2022). Therefore, the curriculum should include instructions, strategies, or support provided to

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students to help them manage the amount of work they are expected to complete, providing students with regular, ongoing information about their performance, understanding, or progress during the learning process, and retrieval practice where students actively recall information from memory. However, digital tools, including AI, can also help students with practice and self-revision, but if used extremely and without control, they may lead students to depend on shortcuts to find answers rather than developing a genuine system of understanding (Sanchez-Ruiz et al., 2024).

In summary, the Summary and Expanded Summary suggest several guidelines for computer science educators. These include providing short activities such as pre-lab quizzes or prediction questions to help students recall before using tools. Practice should also be organized so that basic concepts are repeated multiple times at different times and in different situations using spacing, interleaving, and spiral methods. The use of digital tools should be controlled with policies such as delaying hints or encouraging students to try on their own first. In addition, learning strategies should be combined with fair support and emotional assistance for students. Finally, student achievement should be assessed through long-term retention tests and real-world tasks, not just immediate post-tests (Yasar et al., 2019; Moraes & Folkestad, 2024; Hsu & Mimura, 2017).

Despite these promising directions, research evidence is still limited. Most studies are descriptive, short-term, or presented at conferences. More comprehensive and long-term studies, such as randomized trials to evaluate combined methods, for example retrieval-first, spiral sequencing and controlled tool use, with delayed retention tests and real tasks, are still very rare (Yasar et al., 2019; Moraes & Folkestad, 2024). Moreover, as digital learning ecosystems evolve rapidly such as AI tutors and new LMS features, continuous reassessment is necessary to ensure pedagogical guidance remains up to date (Sanchez-Ruiz et al., 2024).

Simply put, the Summary and Expanded Summary explain that digital amnesia happens because students rely too much on digital tools, receive excessive amounts of information, and not all students have equal access. However, this problem can be addressed through proper teaching approaches. Instead of rejecting digital tools, the solution is to use them in a structured way, for example, through recall activities, step-by-step practice, and fair support for all. This approach helps computer science students not just to find answers using tools but truly understand concepts and build skills that can be applied in the future.

Table 3.1. Key Literature Derived from Scopus-AI (Summary and Expanded Summary)

Author(s)	**Year**	**Title**	**Source Title**	**Cited By**
Skulmowski, A.	2023	The cognitive architecture of digital externalization	Educational Psychology Review	58
Khrapov, S. A., & Baeva, L. V.	2022	Digitalization of educational space: Emotional risks and effects	Voprosy Filosofii	71
Petrasuc, A.-M. G., & Popescul, D.	2019	The dark side of digitalization: ICT influence on human learning processes	eLearning and Software for Education Conference Proceedings	35
Frolova, E. V., Rogach, O. V., & Ryabova, T. M.	2020	Digitalization of education in modern scientific discourse: New trends and risks analysis	European Journal of Contemporary Education	82
Hsu, W. C., & Mimura, Y.	2017	Understanding the secondary digital gap: Learning challenges and performance in college introductory programming courses	Proceedings of the IEEE 9th International Conference on	96

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			Engineering Education (ICEED)	
Yasar, O., Veronesi, P., Maliekal, J., & Tillotson, J. W.	2019	Memory retrieval strategies to help retain STEM content knowledge	ASEE Annual Conference and Exposition, Conference Proceedings	44
Moraes, M. C., & Folkestad, J. E.	2024	WIP: Analyzing students' practice behaviors in an introductory computer science course and monitoring their practice behaviors in a subsequent class	Proceedings - Frontiers in Education Conference (FIE)	9
Sanchez-Ruiz, L. M., Morano-Fernandez, J. A., Herrero-Debon, A., & Caro, C. D.	2024	Exploring digital learning pathways: Student use of online information resources and the role of AI	World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)	12

3.2 Concept Map

The concept map generated from Scopus in Figure 3.1 shows the main thematic clusters underlying memory retention challenges in computer science education. Four main domains emerge: curriculum design, learning technologies, student engagement, and the digital classroom environment. In curriculum design, higher education frameworks and introductory computer science courses are highlighted as critical contexts where memory challenges are most evident. Learning technologies show two perspectives, namely the balance between the advantages and disadvantages of digital tools in shaping cognitive retention. Student engagement, which emphasizes on innovative practices and the first-year experience, is identified as an important factor that can either reduce or worsen digital amnesia. Finally, the digital classroom focuses on ways to measure and monitor student behavior, for example through the Digital Amnesia Scale (DAS) and the issue of distraction. Overall, the concept map shows that digital amnesia occurs due to a combination of teaching methods, technology use, and student behavior, which influence how computer science students remember and apply knowledge.

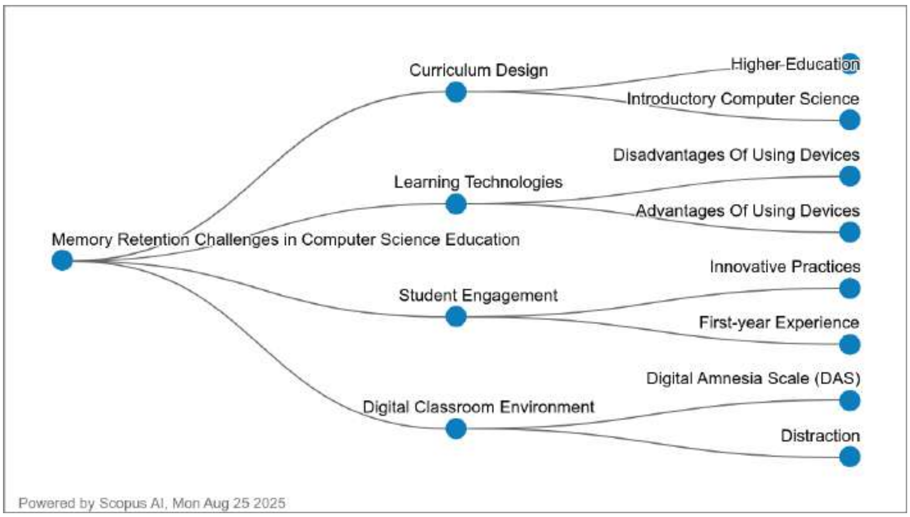

Figure 3.1: Concept map memory retention challenges in computer science education

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3.2.1 Memory retention challenges in computer science education

The challenges to maintain memory retention in computer science learning is quite complicated, especially in a digital learning environment. One of the challenges is the difficulty of collecting and analyzing student retention data among computer science undergraduate students. This situation where fragmented datasets, different background of students and different policy applied from the institution may cause difficulty in monitoring (Stephenson et al., 2018; Miller et al., 2019). Other than that, the limitation of the overall data also limits the educators to identify the students' problem and the effective way to assist them.

Moreover, students are facing difficulties in understanding the basic concept in computational process including on how memory is organized and how the program is working. This basic concept is very important because students should understand the computational process that is related to the physical devices. If they fail to master these, it will increase the cognitive load, worsen digital amnesia and hinder long-term knowledge. To solve this problem, the strategy in teaching process should be clear and precise, scaffolded and provide repeated exposure.

Other than that, the learning techniques and styles also influence the retention. Research shows that the practice of doing revision regularly, applying mix or alternate learning strategy and practicing a skill to improve performance can increase the effectiveness and reduce forgetting (Moraes & Folkestad, 2024). Yet, many students rely on their poor habits such as last-minute study and passive note taking where they do not engage with the materials, which weaken the retention. Besides, course structures should encourage learning style which based on evidence, supported by formative assessment which monitor student understanding and provide feedback, that strengthening memory by actively trying to remember information.

Retention relies on a variety of cognitive, socio-emotional, and structural issues - prior preparation, cognitive load, motivation, sense of belonging, as well as external pressures, such as financial or family-related issues (Salguero et al., 2021; Dorodchi & Dehborgi, 2017; Li et al., 2024). For nontraditional learners, academic and personal demands conspire to create extra barriers to learning. This research demonstrates that relational retention involves cognitive, personal, and social factors.

Course design can influence retention; for example, a spiral curriculum that introduces core concepts and revisits them at increased complexity can lead to improved performance and persistence (Lionelle et al., 2022). Redesigning the introductory sequence and using student-centered or project-based approaches are associated with increased persistence (Turner et al., 2007). These suggestions demonstrate that thoughtful design of instruction can mitigate cognitive overload related to digital amnesia. CBL or even rethinking notions of accountability may foster more learning or engagement.

3.2.1.1 The relationship between memory retention challenges in computer science education and curriculum design

Issues with memory retention in computer science learning are intricately linked with curricular format and delivery within online digital environments. A notable difficulty of students is threshold concepts such as memory organization and program execution. Kyriakou et.al (2025) noticed that mastering main memory organization is both foundational and complex, as well as possibly being an impediment to understanding overarching principles in computer science. Without curricula that design scaffolded and iterative instruction on these concepts, students can suffer from poor long-term retention and forget, which limits the ability to apply knowledge to subsequent, more advanced courses.

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Curriculum redesign can help to mitigate these challenges. Lionelle et al. (2022) have demonstrated that spiral pedagogy, which revisits core concepts in successively deeper contexts, has positive implications for both student performance and the retention of knowledge. By incorporating spacing, interleaving, and retrieval practice into the course, we reinforce desired immediate outcomes, as well as retention of information to be applied in either subsequent semesters or courses. These aspects bring a curriculum structure more closely aligned with cognitive science principles to help facilitate memory retention in computing education.

Active learning demonstrates the importance of design decisions. Liao and Ringler (2023) report that while active learning results in an increase in engagement and collaborative problem solving, assessing individual knowledge gains may be more difficult. Group-based learning needs to be balanced with individual reinforcement opportunities which situated in individual learning, for example, reflective quizzes or checkpoints, so the instructor can gauge content retention.

Strategic approaches related with coursework can also enhance long-term learning. Moraes and Folkestad (2024) asserted that interleaving and spaced retrieval can help create robust knowledge. When interleaving and spaced retrieval are leveraged in assignments, labs, and assessment, they build mental anchors that have more staying power than just preparing for an exam.

In conclusion, memory retention issues in the field of computer science education are a result of curricular design. Threshold concepts require scaffolded instruction, spiral pedagogy offers structural redundancy, active learning requires some form of individual evaluation, and retrieval-based strategies promote long-term retention of knowledge. All of these suggestions highlight the need for a curriculum that is informed by cognitive principles in order to improve knowledge retention and student success.

3.2.1.2 The relationship between memory retention challenges in computer science education and learning technologies

Retention remains a difficult challenge in computer science education and specifically, digital learning environments because technology shifts occur much quicker than students can retain knowledge. The first problem is data collection and tracking. Several conductors of studies have found it very difficult to monitor retention patterns in undergraduate computer science literature, (Stephenson et al., 2018), (Miller et al. 2019). Poorly monitored data restricts the instructor's ability to see retention breakdowns and excludes them from developing evidence-based solutions. Solving these challenges in learning experiences is vital because we need systems that provide actionable detail into the student's learning behaviour when aspiring to make meaningful interventions related to improving retention.

Learning technology is suddenly appearing as a solution to potential challenges that could help with retention which improving a student's motivation & engagement. While developing web-based educational games for programming instruction, Piteira and Haddad (2011) noted significantly higher student interest and participation in games compared to lectures. Positive impact on retention was indirect and relied on the more active feature of engagement. Most acquisition interfaces included principles commonly associated with memory enhancement. They included features such as spaced repetition and feedback methodology, and scaffolding naturally represent learning and memory enhancement principle. To date, no program of this nature has been able to expand the program while effectively aligning the engagement model with curricular goals.

Mobile technologies also support memory retention. Carlson et al. (2020) suggested that mobile technologies contributed to confidence and retention in computer engineering courses by providing access to learning materials in a flexible manner which afforded further exposure to complicated concepts and was beneficial in reducing cognitive load.

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Open educational resources (OER) provide another route. Cacho et al. (2016) studied an OER to aid students' simulation of memory hierarchy revealing improvement in student performance and suggest that different forms of exposure to threshold concepts develops memory retention. More recently, predictive analytics has emerged. Li et al. (2024) demonstrated a predictive analytics model used to identify at-risk students and help inform targeted injurious intervention.

In conclusion, resigning memory retention in computer science education is a complicated issue to address, however technologies like serious games, mobile technologies, OER and predictive analytics provide some promise. These approaches also connect to key principles, including spaced practice and retrieval strengthening, acts of engagement. However, most research studies spoke about retention broadly, without providing a deep analysis or understanding of memory processes. Future work must merge cognitive psychology with technological advancements to create scalable, evidence-based approaches, suited to the context of computer science education.

3.2.1.3 The relationship between memory retention challenges in computer science education and student engagement

Memory retention is a concern in computer science education, particularly in digital learning environments where engagement drives learning outcomes. Learning Engagement Strategies (LESs) and High-Impact Practices (HIPs) increase retention and completion rates in STEM fields (Ramasamy, Singsen, & Walia, 2024). Both LESs and HIPs advocate for active participation, peer-to-peer collaboration, and support student reflection, and all of which support the long-term retention of technical knowledge. If students do not engage with the content, they have little chance to effectively encode and recover what they learned.

The use of interactive multimedia, gamification, and student centered course design contribute to sustained engagement in digital learning environments. Concurrently, technology-mediated interactive activities may also serve to increase student motivation towards the course and improve memory consolidation (Ullah & Anwar, 2020). Using multiple modes of interaction reduces cognitive overload and improves retention of programming concepts; however, technology that has not been implemented well can distract rather than enhance learning and be mitigated through intentional instructional design.

Examiner and instructor intervention functionally can make a difference as it influences cognitive processing and learning outcomes. Feed-forward from the examiner, organizational support for learning, and scaffolding, all support learner cognition and outcomes of learning (Szabo, Falkner, Knutas, & Dorodchi, 2018). Specifically, the lecturers' help with breaking-down complex programming tasks, providing low stakes/no-stakes tests and/or assessments, and presenting complex topics gradually provide repetition and application to support memory. The threat without intervention is students’ risk (1) disengagement with learning and (2) weak retention of foundational core concepts in computer programming.

Capturing data and analyzing engagement data present challenges, and gaps in critical reading and analytical writing, foundational skills will constrain students' abilities to read and engage with technical material (Fuad & Deb, 2017).

In conclusion, memory retention theory in computer science education will relate along the lines of learner engagement. Technological and pedagogical approaches such as interactive technologies, to gamification, and examiner or instructor interventions, provide some successful examples to consider, which impact learners’ memory by providing productive engagement, to feedback, to skills development, in the design of future curricula.

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3.2.1.4 The relationship between memory retention challenges in computer science education and digital classroom environment

Memory retention problems are more common in computer science education, especially in digital learning. Students depend heavily on technology, receive information quickly, and have limited opportunities for direct collaboration and interaction. Students were unable to recall and apply vocabulary and foundational concepts that should have been prior knowledge. Whelchel (2007) highlighted the importance of prior knowledge when mastering complexities or advanced knowledge and suggested weak reinforcement in remote formats frequently leads to increased misconceptions and slower progress when scaffolding learning is not present.

Cognitive load also affects retention. Gerjets et al. (2014) describe how basic aspects of a digital environment can easily overwhelm working memory for example information overload, multitasking, switching between platforms, too much detail in instructions. When these aspects occur together without careful design, students may understand the lesson quickly in the short term. However, this can weaken long-term understanding and knowledge transfer. Cognitive Load Theory highlights that materials must be designed for the anticipated cognitive load of working memory, which is especially salient in a digital context given the risk of distractions.

Staying on top of retention whether online or in-person is troublesome. According to what Stephenson et al. (2018) and Miller et al. (2019) found, analytics can be sporadic and incomplete, which makes identifying learners at risk more difficult. Some of the difficulty stems from how analytics capture learners online in a way that does not capture the engagement in a face-to-face environment, and sometimes data in analytics causes incentive delays in teachers engaging with learners struggling to retain what they have learned.

Digitalization introduces new challenges to retention. Khrapov and Baeva (2023) argue that overdependence on digital support (aids and search processes) causes cognitive overload and decreased active recall potential. Kusnadi et al. (2025) briefly speak about other pressing challenges, such as device disparity/accessibility limitations, unstable internet connectivity limitations, and teacher training limitations that also impact retention.

A potential workaround for a different focus on retention is recommending that educational researchers normalize embedding retrieval-based evidence into digital course design. Yasar et al. (2019) established that spaced and interleaved retrieval is superior for long-term learning, while Kyriakou et al. (2025) examined the reinforcement of the threshold concept through an integrated approach involving retrieval. This research suggests that digital classrooms promote equal access and accessibility to manage learners' limits of cognitive load and enable the development of active memory formation would have a positive impact on retention.

3.3 Topic Expert and Representative Contributions

Scopus AI identified several authors working on contextual knowledge tracing, adaptive learning, and models of learning and forgetting. Among the verified contributions, Chen et al. (2023) examined how exercise difficulty, learner behaviour, knowledge acquisition, and forgetting can be incorporated into contextual knowledge-tracing models.

This work is relevant because it demonstrates how adaptive learning systems can model changes in learners' knowledge states and account for forgetting over time. However, the study concerns contextual knowledge tracing rather than digital amnesia among computer science students specifically. It is therefore interpreted as supporting evidence for adaptive and personalized learning, rather than as direct empirical evidence of digital amnesia in computer science education.

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The topic-expert analysis also showed that author prominence alone should not be treated as evidence of conceptual relevance. Authors were retained only when their Scopus profiles, publication records, and representative studies showed a clear connection to memory, forgetting, adaptive learning, or digital education.

3.4 Emerging Themes

The analysis reveals three themes—consistent, emerging, and new—that guide responses to digital amnesia and improved learning outcomes in computer science education. The theme of digital competencies and adaptability demonstrates that students and educators require skills to work within digital environments. Digital literacy, as Ilomäki et al. (2016) observe, includes meaningful ways of using digital tools meaningfully and not merely technical knowledge. In computer science, adaptable ways of working with shifting technologies are paramount. Students need to incorporate tools into problem solving while ensuring their conceptual understanding remains intact.

Educators' digital competence also affects the quality of pedagogy and the integration of technology in teaching (Instefjord & Munthe, 2017). Without these foundations, efforts to address retention challenges are limited.

The rising theme of memory retention strategies reflects increasing attention to the cognitive demands of digital learning. Techniques such as mnemonics, chunking, and spaced repetition are now common in e-learning platforms to promote durable learning (Carpenter et al., 2022). Spaced repetition has shown strong effects on long-term retention compared to massed practice (Cepeda et al., 2008). In computer science, these strategies are critical for sustaining knowledge of syntax, algorithms, and theoretical principles that may otherwise be lost through dependence on digital references. Immersive approaches such as virtual reality also provide context-rich environments that improve recall (Parong & Mayer, 2021).

A theme around personalized learning through artificial intelligence (AI) shows promise. AI-driven systems that note learner behavior, provide personalized content adjusted to cognitive needs, and provide retrieval prompts at the most optimal intervals (Chen et al., 2020). In computer science, this includes modulating task difficulty, recommending specific practice, and providing interventions to lessen knowledge decay for a learner (Zawacki-Richter et al., 2019).

These themes indicate a model that unites digital literacy, evidence-based retention strategies, and AI-supported personalisation. Specifically, in computer science education, the application of this model provides a framework for building resilient and adaptive learners.

4. Conclusion

This study examines digital learning with a focus on the challenges and opportunities of digital amnesia and memory retention among computer science students. The results indicate three themes. First, the highlight of digital competencies and adaptability emphasizes that digital literacy, as it relates to students and educators with emerging technologies, is critically important. Second, memory retention strategies are highlighted in the results, which reflect the cognitive burden of working in an online context (as opposed to a physical one) and requires, use of memory strategies such as spaced repetition, chunking, and immersive learning. Third, personalized learning driven by artificial intelligence (AI) refers to learning that adapts the instructional or learning support materials to what the learner may need, and which can, to an extent, mitigate knowledge loss.

In terms of theory, this research contributes to the body of literature that lies at the intersection of cognitive psychology, educational technology, and pedagogy. The emphasis is on using technology in conjunction

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with established ideas, including distributed practice and cognitive load theory, to optimize outcomes. Framing the outcome of AI-infused personalization as an extension of models that lead to adaptive, data-informed frameworks is an educational breakthrough that allows for the mitigation of digital amnesia.

Practically, the findings have implications for educators, policymakers, and developers. For educators, combining digital literacy with memory reinforcement strategies can improve teaching. For policymakers, the importance of digital competencies, especially when treated as core skills in curriculum, becomes apparent based on the findings. For developers, AI-driven personalization will provide opportunities to create systems that favour memory consolidation, rather than merely content delivery.

There are limitations associated with this study. The findings were derived from a scoping evidence-mapping synthesis rather than primary empirical testing, and much of the included evidence was context-specific, which limits the transferability of the conclusions. Issues around unequal access to technology and the ethical issues with personalization raised by AI remain unresolved. Future research should also follow empirical, long-term and cross-cultural design while factoring in any ethical and social concerns.

Future research should operationalize cross-cultural testing through coordinated studies in introductory programming courses across institutions and national contexts. A practical design could compare a control group using conventional coding environments and unrestricted online resources with an intervention group using an AI tutor configured with retrieval-first prompts and delayed hints. Outcomes should include immediate course performance, delayed recall after four to six weeks, debugging accuracy, code-tracing ability, and transfer to unfamiliar programming problems. The analysis should also account for prior programming experience, digital competence, language background, and access to suitable devices. Such a design would determine whether AI-supported learning workflows produce durable knowledge rather than merely improving short-term task completion.

In summary, tackling digital amnesia needs digitally oriented skills, memory retention methods, and AI-based personalization. Addressing digital amnesia therefore requires more than increasing access to educational technology. Computer science curricula should regulate how tools are used, provide repeated opportunities for active retrieval, and evaluate whether students can retain and transfer knowledge after instructional support has been removed. Combining these principles with carefully designed adaptive technologies may support both immediate learning and durable conceptual understanding.

Acknowledgments
The authors would like to extend their heartfelt gratitude to Universiti Teknologi MARA (UiTM) Kedah Branch for their steadfast support.

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eISSN: : 2682-7840