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The Role of Self-Regulated Learning in Enhancing Computational Thinking Skills: A Systematic Literature Review and Bibliometric Analysis

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Abstract: Self-regulated learning (SRL) is widely recognized as one of the strongest predictors of academic success; however, its specific role in fostering the development of computational thinking (CT) has not been fully scrutinized. Objective: This study aims to map the development of research, identify key trends and themes, and analyze the intellectual structure of the literature at the intersection of SRL and CT through a systematic literature review and bibliometric analysis. Methods: A total of 38 Scopus-indexed journal articles were selected following the PRISMA 2020 guidelines, and their methodological quality was appraised using a structured five-criterion rubric adapted from established critical-appraisal criteria (Kmet et al., 2004). VOSviewer (v1.6.20) was used to visualize keyword co-occurrence networks and co-authorship networks, whilst Bibliometrix (R package v4.2.3) was used to analyze publication trends, author productivity, source impact, and thematic evolution. Findings: The analysis revealed significant growth in publications from 2017 to 2026, peaking in 2025. The United States, Taiwan, and China were the main contributors. Key thematic clusters included SRL scaffolding in programming education, metacognition and CT assessment, and personalized learning environments. The reciprocal relationship between SRL and CT is identified as the most prominent research trajectory in the recent period. Conclusion: This review highlights critical research gaps, particularly the scarcity of longitudinal studies and the still-limited representation of the Global South, whilst providing a roadmap for future empirical and pedagogical investigations at the intersection of SRL and CT.

Keywords: self-regulated learning, computational thinking, bibliometric analysis, systematic literature review, VOSviewer, Bibliometrix.

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INTRODUCTION

In the ever-changing educational landscape of the 21st century, computational thinking (CT) has taken on an increasingly central role as a competency required of learners to navigate a technology-rich world. CT is widely understood as a set of problem-solving processes involving abstraction, decomposition, pattern recognition, algorithmic thinking, and logical reasoning (Wing, 2006, 2008). Originating in computer science, CT has transcended its original boundaries and is now recognized as a fundamental cognitive skill applicable across disciplines. Successive reviews of the field have since consolidated its definitions, instructional strategies, and assessment practices (Grover & Pea, 2013; Shute et al., 2017; Hsu et al., 2018). Against the global backdrop of digital integration, the academic community broadly recognizes that cultivating learners' adaptive competencies to address multidimensional challenges (Cao, 2023; Christensen, 2023) is critically important. Multiple countries have integrated computational thinking into their national curricula (Vinnervik & Bungum, 2022), framing it not as a narrow, standalone technical skill, but as a broad educational paradigm suited for the technology-driven era.

Meanwhile, self-regulated learning (SRL) has a long history as an area of importance within the educational literature and one of the strongest predictors of academic performance. Zimmerman (1989) first conceptualized SRL as learners' active engagement in their own learning process through metacognition, motivation, and behavior. Built upon a cyclical model comprising three phases forethought, performance, and self-reflection SRL enables learners to set goals, monitor progress, and evaluate learning outcomes independently (Zimmerman, 2002). Comparative reviews have since consolidated the major theoretical models of SRL and clarified their points of convergence (Panadero, 2017). Across various educational contexts, SRL is consistently associated with higher academic achievement, deeper conceptual understanding, and more effective transfer of knowledge across tasks (Pintrich, 2000; Schunk, 2011). Given its emphasis on autonomous and goal-directed cognition, SRL is theoretically well-suited to supporting the development of CT, particularly in environments where learners must engage in iterative problem-solving, debugging, and algorithmic design all of which require metacognitive awareness and continuous self-monitoring.

Over time, a number of studies have begun to examine the intersection of SRL and CT, particularly in the context of programming and computer science education. Various studies indicate that learners with stronger SRL dispositions, particularly in metacognitive regulation and effort management, tend to demonstrate higher levels of CT (Li et al., 2025; Song et al., 2021). Structured SRL interventions (e.g., reflective journals, self- monitoring prompts, and collaborative problem-solving tasks) have been found to promote CT competencies such as decomposition, pattern recognition, and algorithmic reasoning (Gu et al., 2025; Kong & Wang, 2024). The bidirectional relationship between SRL and CT has also been reported in primary and secondary school contexts, indicating the complementary role of two constructs across different stages of development (Kong & Wang, 2024). However, the literature has been poorly integrated, spanning different educational levels and geographical areas with varied methodological approaches which limits the utility of this information leading to incoherent and non-generalizable conclusions.

Despite this emergence, wide-ranging and systematic syntheses at the intersection of SRL and CT remains rare. While, existing reviews have typically investigated CT in isolation for example, focused on its use in mathematics or STEM education (e.g., Zhang & Nouri, 2019; Tang et al., 2020), and they have not quantitatively integrated it with SRL through bibliometric mapping. Bibliometric analysis, which is a quantitative method for exploring scientific publications that research patterns, thematic trends and the structural dynamics of a field of study (Donthu et al., 2021), can be successfully applied to diverse environments. In this work, we present the results of a dual approach (D A) that provides an objective synthesis when used together with Systematic Literature Review (SLR) based in PRISMA 2020 guidelines to ensure better quality of data (Lim & Kumar, 2024). As highlighted by Riskawati et al. (2025) The integration of bibliometric analysis with systematic review methods improves the impact of research evaluation and evidence synthesis in the field. This time series combination approach should be one of the largest strides forward in our knowledge of how the measures of SRL drive CT across a wide variety of educational contexts.

Hence, this study begins with an integrated analysis by conducting systematic literature review (SLR) along with bibliometric analysis of Scopus indexed SRL oriented studies published between 2017 and 2026 that related to the enhancement of CT skill. This period was selected for a reason: starting from 2017 there has been a volume of empirical research embedding self-regulative learning (SRL) strategies in CT-focused instruction that is coinciding with global momentum to reform K-12 computer science education, as well as the spread of informal and formal digital learning environments. This study implements VOSviewer and Bibliometrix to develop co-occurrence networks of keywords, maps representing the evolution of themes over time, co-authorship networks, as well as citation analysis facilitating multi-dimensional insights into the SRL and CT research landscape (Mukherjee et al., 2022).

Based on the above context, this study seeks to answer the following four research questions:

1. What are the trends in annual SRL and CT research publications from 2017 to 2026?
2. Which journals, authors and countries have made the most productive contributions to this field?
3. What is the structure of the collaboration network among authors in the SRL and CT domains?
4. What are the main research themes and how have they evolved over the study period?

This study makes a unique contribution as the first integrated SLR and bibliometric analysis to focus exclusively on SRL and CT as co-constructs in educational research. By uncovering the intellectual structures, thematic clusters, and collaborative networks underpinning this field, the study offers actionable insights for educators, curriculum designers, and researchers seeking to use SRL strategies in CT-oriented instruction. Furthermore, the identification of unaddressed research gaps particularly the scarcity of longitudinal studies and the still-limited representation of Southeast Asian and Global South contexts positions this review as a strategic guide for future empirical investigations.

■ METHOD

Research Design

This study employed an integrated design combining a systematic literature review (SLR) and bibliometric analysis. Bibliometric analysis is a quantitative research method that evaluates the performance of various elements of scientific work, including publications, authors, keywords, journals, institutions, and countries, by utilising visualisation techniques to present analytical results and measure scientific output (Donthu et al., 2021). This method minimizes the subjectivity inherent in traditional narrative reviews by offering an alternative based on empirical data (Riskawati et al., 2025). Together with an SLR-process with the PRISMA 2020 protocol (Page et al., 2021), the quantitative mapping and qualitative synthesis of this dual approach offers a more comprehensive, systematic and hence replicable overview of the literature (Lim & Kumar, 2024).

The analytical backbone of this study comprised four dimensions: (1) annual trends and growth rates of publications; (2) leading journals, authors and countries; (3) collaboration networks among authors; and (4) patterns from keywords co-occurrence and thematic evolution across three different periods. The third contribution is a thematic synthesis that complements the bibliometric mapping and provides the fields of SLR strategies in terms of how it has been implemented to support CT development in different educational contexts.

Search Strategy

The data were retrieved from the Scopus database on 10 May 2026. We chose Scopus because its broad disciplinary coverage, standardized metadata (including author keywords and affiliations), and Citation Counts is seamlessly adopted in the bibliometric approaches used in this paper VOSviewer and Bibliometrix making it the most common data source for research of bibliometric mapping in educational research (Pranckutė, 2021). It should thus be emphasized that the selection of one single database is an intentional methodological compromise. Scopus was chosen because it maximizes metadata consistency and, therefore, the reproducibility of the indicators reported below, but this decision limits coverage relative to a multi-database strategy and excludes other relevant work accessible elsewhere. The Limitations section discusses the implications of this decision for corpus completeness and findings generalisation in critical terms. A Boolean search strategy was created to retrieve the entries related to SRL and CT at the same time as follows:

("self-regulated learning" OR SRL OR "self-directed learning") AND ("computational thinking" OR "algorithmic thinking")

The following filters were then applied in sequence: (1) publication year restricted to 2017-2026, (2) document type restricted to journal articles, (3) language restricted to English, and (4) source type restricted to journals. The initial search yielded 94 records. After applying these filters, 48 documents remained for the screening stage. All metadata, including title, abstract, author keywords, author name, institutional affiliation, source title, year of publication, and number of citations, was exported in CSV format for further analysis.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were established prior to screening to ensure transparency and the reliability of the process. All criteria were applied through two sequential screening stages: title screening (Stage 1) and abstract screening (Stage 2). Articles were included if they met the following conditions: (I1) discussed SRL or self-directed learning as the substantive focus, (I2) examined CT or algorithmic thinking as the main construct, (I3) were set within the context of formal education, (I4) were peer-reviewed, indexed journal articles, (I5) are written in English, (I6) were published between 2017 and 2026, and (I7) have a sufficiently comprehensive abstract. Articles were excluded if SRL was only mentioned in passing without a substantive link to CT, the research context was outside the field of education, or the document type was an editorial, note, or book review.

Selection Process (PRISMA Workflow)

The article selection process followed the PRISMA 2020 guidelines (Page et al., 2021). From an initial pool of 94 Scopus records, 48 documents remained after applying the predefined filters, with no duplicate entries found. Stage 1 (title screening)Two articles were excluded in this stage as topics were very clearly out of the scope of SRL or CT: one was a general bibliometric analysis of an educational journal, and one examined SRL with respect to business management. This resulted in 46 articles remaining for Stage 2. Based on title and abstract screening, eight more articles were excluded, mainly because SRL and CT were not linked to one another, only briefly referenced together or the context of research was not in formal education. A final 38 eligible articles made up the corpus for bibliometric and systematic thematic synthesis analysis. PRISMA flow diagram (Fig 1)

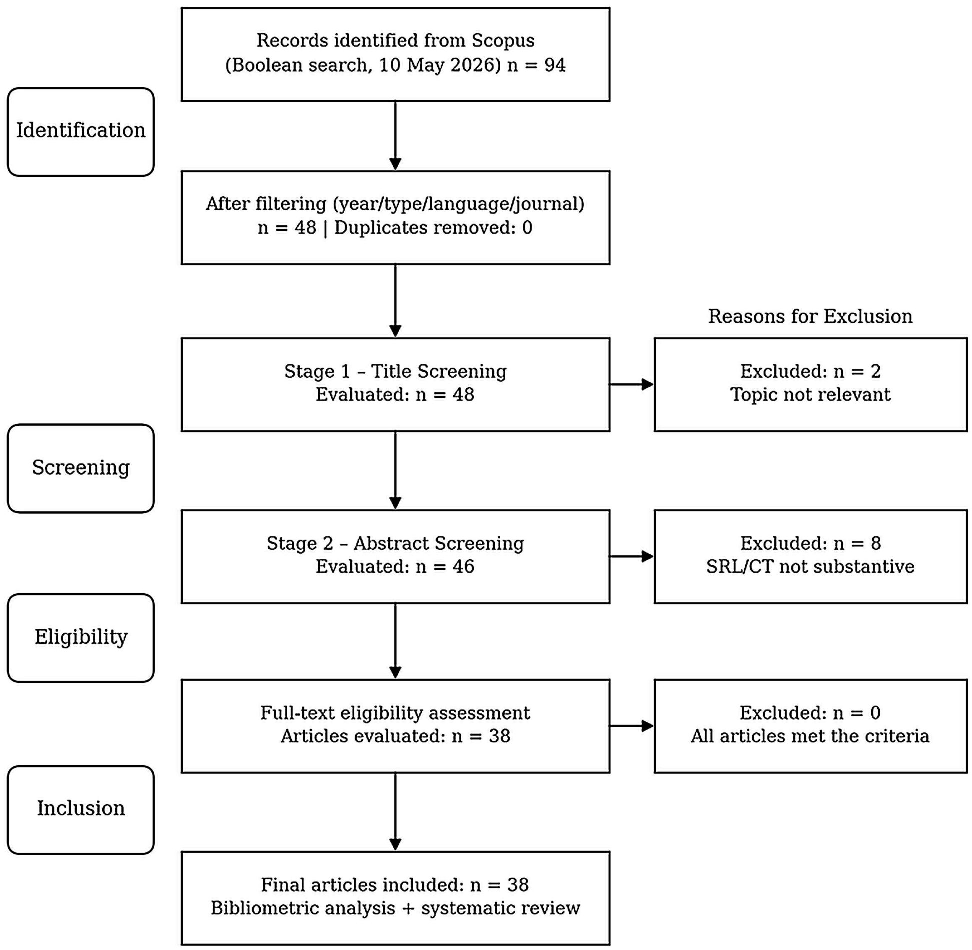

Figure 1. PRISMA flowchart for article selection

Quality Assessment and Risk of Bias

Although all 38 articles in the corpus had already been peer reviewed and met the indexing criteria of the Scopus database providing minimum levels of methodological quality, a systematic appraisal was undertaken to assess the methodological rigor of individual studies and mitigate bias risk across thematic synthesis. Using a five-criterion rubric (that was adapted from Kmet et al.'s standard criteria for quality assessment), a two-appraiser system assessed the appraisal (2004) which were chosen because each provides a single numeric rating system to score quantitative, qualitative and mixed-methods designs the three types of studies represented in our corpus. Included articles were subsequently scored on this rubric (see below), with scoring based on the information regarding methodology included in each article.

This involved evaluating the following five criteria: (1) The extent to which aims and questions are clear and relevant, (2) The appropriateness of the research design, (3) Validity and reliability of measures self regulated learning & computational thinking, (4) Transparency/adequacy of data collection & analysis procedures, and (5) Coherence between findings, data, conclusions. Each criterion was scored with 0 (not met), 1 (partially met) and 2 (fully met) for a maximum of 10 points. Each study was rated as either high (8-10), moderate (5-7), or low quality (0-4) based on the total score. A summary of the appraisal across all 38 studies is provided in Table 1.

Table 1. Summary of the methodological quality appraisal of the 38 included studies

Appraisal criterion	Fully met (2)	Partially met (1)	Not met (0)	Mean (/2)
C1 Clarity and relevance of aims and research questions	38	0	0	2.00
C2 Appropriateness of the research design	28	10	0	1.74
C3 Validity and reliability of the SRL and CT measures	11	27	0	1.29
C4 Transparency of data collection and analysis	24	14	0	1.63
C5 Coherence between data, findings, and conclusions	25	13	0	1.66
Overall quality score (maximum = 10 per study)	-	-	-	8.32

Note: Each criterion was scored 0 (not met), 1 (partially met), or 2 (fully met), giving a maximum of 10 points per study; the rubric was adapted from Kmet et al. (2004). Studies were graded High (8–10), Moderate (5–7), or Low (0–4). Of the 38 studies, 28 (73.7%) were rated High and 10 (26.3%) Moderate, with none in the Low band. The mean total score was 8.32 (median = 9; range = 6–10), indicating a methodologically sound evidence base with a low overall risk of bias.

The corpus was appraised as largely methodologically sound, with associated risk of bias low. The average score for the quality assessment was 8.3 (range 6-10), most studies (28 out of 38, 73.7%) were rated high quality and remaining moderate quality (10 out of 38,26.3%, and no one who had a low category study) This pattern matches how filtering takes place during the peer review and Scopus indexing process, hence no article was excluded based on quality, rather, assessment served to confirm the reliability of the evidence base and worked instead to determine how much interpretive weight was given toward individual studies in synthesis. The most common methodological limitation was that the majority of studies used cross-sectional and short-term intervention designs along with self-reported measures of self-regulated learning, which limit causal inference. This recurring pattern may introduce bias and will be addressed in the limitations of this review.

Data Analysis

Two complementary tools were used to conduct the bibliometric analysis: VOSviewer (version 1.6.20; Van Eck & Waltman (2010)) and Bibliometrix R package (Version: 4.2.3; Aria & Cuccurullo (2017)) through its RStudio-based Biblioshiny web interface. Bibliometrix was utilized to calculate the annual publication trend, rank authors productivity, obtain Source Impact metrics and citation indicators, and create the theme evolution Map. VOSviewer was used to build and visualize the co-authorship network and keyword co-occurrence map.

In VOSviewer, full counting was performed for key words with a minimum number of occurrences set to two; hence, only keywords appearing in at least two papers were included in the network creation process. Because the corpus is modest in size (38 articles), this lower threshold was adopted deliberately to preserve the full range of relevant topical variation that a higher cut-off would otherwise have discarded. In terms of authors and sources, three documents were needed to take part in the construction of a network. The resolution parameter (resolution = 1.00) was retained as recommended for the smart local moving algorithm in VOSviewer, and minimum cluster size was set to one item. For the keyword map, we used overlay visualisation mode where a colour gradient encodes the average publication year of each keyword attempting thereby to separate long-standing from newly-emerging terms.

Thematic evolution analysis was conducted on the author keywords (DE field) using Walktrap clustering algorithm and two cutting points, 2021 and 2024 that divides the corpus into three periods: 2017-2021, 2022-2024 and 2025-26 in Biblioshiny. The first cut-off point was established in 2021, the year when the annual distribution of publications shows a trend change, and the second in 2024 to isolate more recent literature. The inclusion index was used, weighted by occurrences of words (including synonyms and related terms), as our measure of thematic continuity between consecutive epochs. The first phase was data cleaning, in which we standardized different forms of author names and institutional affiliations to make co-authorship mapping more accurate prior to the analysis. The key bibliometrical characteristics of the 38 articles are summarized in Table 2.

Table 2. Key information on the data collected

Description	**Results**
Time range	2017-2026
Database	Scopus
Search date	10 May 2026
Initial records (Boolean search)	94
Records after filtering	48
Duplicates removed	0
Excluded - Stage 1 (title)	2
Excluded - Stage 2 (abstract)	8
Final articles included	38
Document type	Journal articles (100%)
Language	English (100%)
Source (journal)	38
Total authors	143
Annual growth rate	24.14%
Average citations per document	11.31
Author keywords (DE)	167
Co-authors per document	3.38
International co-authorship	14.58%
Bibliometric tool 1	VOSviewer v1.6.20
Bibliometric tool 2	Bibliometrix R v4.2.3 + Biblioshiny
Reporting standard	PRISMA 2020

■ RESULT AND DISCUSSION

RQ 1. What is the trend in annual research publications by SRL and CT from 2017 to 2026?

A bibliometric analysis of the 38 articles included reveals a consistent upward trajectory over the period 2017-2026, with an average annual growth rate of 24.14%. Examining the annual distribution, only one article was published in 2017 and none at all in 2018 and 2019, illustrating just how nascent this research area was initially. Output began to rise markedly from 2020, and by 2021 there were four publications, a pattern consistent with the global surge in technology-based education research triggered in part by the sudden shift to online learning during the COVID-19 pandemic.

The growth rate continued to rise through 2022 (two articles), 2023 (six articles), and 2024 (nine articles), with 2025 proving to be the most productive year with ten articles. The five articles recorded for 2026 with data collected in May of that year suggest that the upward trend is continuing with no signs of slowing down. Figure 2 illustrates this development as a combined chart, with the annual output shown as bars and the cumulative total superimposed as a trend line.

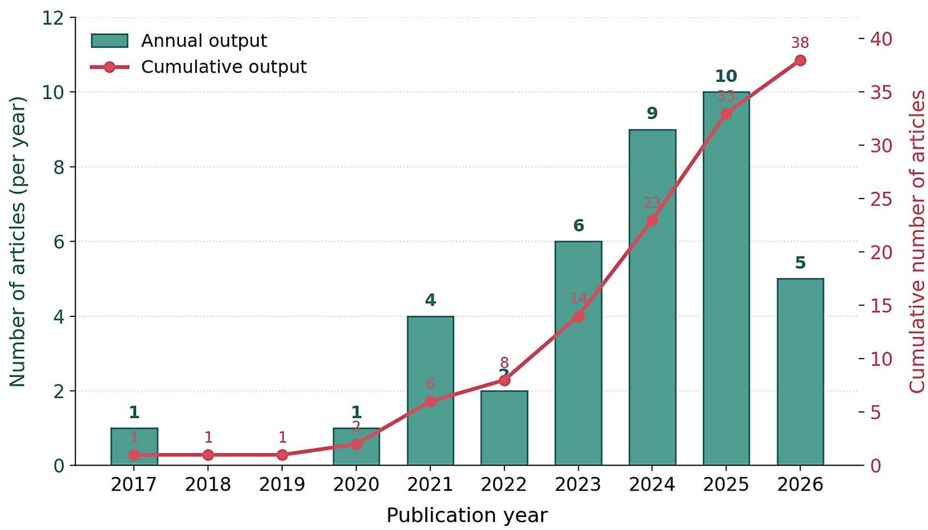

Figure 2. Annual scientific output of SRL and CT research (2017-2026)

Several factors appear to be converging to drive this growth. Firstly, the mainstreaming of CT education into national curricula, particularly in the United States, Taiwan and China, has created institutional demand for evidence-based instructional models, which has naturally directed researchers' attention towards SRL as a framework for designing effective CS learning environments (Vinnervik & Bungum, 2022). Second, the emergence of intelligent tutoring systems and AI-based learning platforms specifically designed to support self-regulated behaviour (Song et al., 2021; Zhong & Zhan, 2025) has raised new empirical questions that researchers are keen to explore. Thirdly, the theoretical maturity of the SRL framework particularly Zimmerman (1989) three phase model and the availability of validated CT assessment instruments (Tsai et al., 2021) have reduced methodological barriers for researchers wishing to explore the relationship between SRL and CT. Together, these three factors have created a fertile academic climate for the development of the intersection of SRL and CT as an increasingly established subfield of research.

RQ 2. Which journals, authors, and countries have made the most productive contributions in this field?

Table 3 presents the ten most productive journals in the SRL and CT literature. Education and Information Technologies leads with five articles (13.16%), followed by the Journal of Engineering Education Transformations with four articles (10.53%). Interestingly, the Journal of Educational Computing Research contributed only two articles but recorded the highest total citations (137), affirming its position as a platform for high-impact work at the intersection of technology and education. The dominance of Education and Information Technologies, which also emerged as the most productive journal in the bibliometric analysis by Riskawati et al. (2025) for CT in physics education, underscores its central role in disseminating interdisciplinary, technology-integrated educational research.

Table 3. The most productive journals in SRL and CT research

Journal	TP	TP (%)	TC	Publisher
Education and Information Technologies	5	13.16	38	Springer
Journal of Engineering Education Transformations	4	10.53	19	RV College
Journal of Educational Computing Research	2	5.26	137	SAGE
Thinking Skills and Creativity	1	2.63	27	Elsevier
Applied Measurement in Education	1	2.63	19	Taylor & Francis
European Journal of Educational Research	1	2.63	11	ERIC-EJ
Computers and Education	1	2.63	13	Elsevier
Sustainability (Switzerland)	1	2.63	7	MDPI
Int. J. STEM Education	1	2.63	0	Springer
Humanities & Social Sciences Communications	1	2.63	1	Springer Nature

Table 4 lists the ten most productive authors. Hegade P. and Shettar A. top the rankings with four publications each (TC = 19); both are from India and have contributed primarily through a series of problem-based learning studies examining CT components in engineering education. Kong S.-C. from Hong Kong follows with two publications (TC = 24), reflecting the impact of his research on SRL in the context of programming assessment. Liang J.-C. recorded the highest total citations (TC = 127), underscoring the significant impact of his work on CT measurement. The diversity of authors' origins from the United States, Hong Kong, Taiwan, Israel, to Japan reflects the international character of th SRL and CT research community.

Table 4. The ten most productive authors in SRL and CT research

Author	TP	TC	Affiliation
Hegade P.	4	19	BMS College of Engineering, India
Shettar A.	4	19	BMS College of Engineering, India
Liang J.-C.	2	127	National Taiwan Normal University, Taiwan
Kong S.-C.	2	24	The Education University of Hong Kong
Broza O.	2	27	Tel Aviv University, Israel
Biberman-Shalev L.	2	27	Beit Berl Academic College, Israel
Chamo N.	2	27	Tel Aviv University, Israel
Chen P.P.	2	2	Fordham University, USA
Chang J.-H.	2	17	National Yunlin Univ. of Sci. & Tech., Taiwan
Kawano Y.	2	6	Osaka University, Japan

Table 5 summarizes the distribution of publications by country. The United States leads with 11 contributions (25.58%), followed by Taiwan (7; 16.28%) and China (5; 11.63%). India ranks fourth with four publications (9.30%), all from the same problem-based learning series. Taken together, these four countries account for 62.79% of all country-attributed records, pointing to a pronounced concentration of scholarly production within a small number of education systems that already have well-established computer science curricula.

The imbalance becomes considerably sharper when the distribution is read against the Global North–Global South divide. If China and India are set aside, the remaining Global South representation consists of four single-article contributions from Brazil, Indonesia, Kazakhstan, and Thailand, amounting to just 9.32% of the corpus. Southeast Asia, a region of more than 600 million people containing several rapidly digitalizing education systems, accounts for only 4.66% (two records), one of which is the sole Indonesian article (Kurniawan et al., 2025). Africa, the Middle East beyond Israel, and Latin America beyond Brazil are absent altogether. A choropleth representation of these data (Supplementary Figure S1) makes the pattern immediately visible: research at the SRL-CT intersection is currently produced by, and largely narrow band of high-income education systems.

This is not merely a descriptive gap. SRL is a culturally situated construct, and CT curricula depend heavily on infrastructure, device access, and teacher capacity. Evidence generated almost exclusively in high-income, well-resourced settings therefore cannot be assumed to transfer to resource-constrained contexts without substantial adaptation and local validation. The geographical concentration documented here consequently constitutes both a substantive research gap and a caution against the uncritical importation of SRL-CT instructional models into under-represented regions.

Table 5. The most productive countries in SRL and CT research

Country	TPC	TPC (%)	Rank
United States	11	25.58	1
Taiwan	7	16.28	2
China	5	11.63	3
India	4	9.30	4
Hong Kong	3	6.98	5
Israel	2	4.65	6
South Korea	2	4.65	7
Thailand	1	2.33	8
Indonesia	1	2.33	9
Kazakhstan	1	2.33	10
Japan	1	2.33	11
Brazil	1	2.33	12

RQ 3. What is the structure of the collaborative network among authors in the fields of SRL and CT?

A co-authorship network generated in VOSviewer shows how researchers working on SRL and CT are organized into collaborative groups. The analysis reveals three distinct collaborative clusters.

The largest cluster is centered on Moallem M. It comprises Vandiver M.J., Billman R.H., Loksa D.C., Christenson L., Harati H., and Atas M.K., all contributors to a co-design-based professional development study (Moallem et al., from an American university. The density of connections reflects the multi-author nature typical of design-based research. A second cluster centers on Li Q. It connects to Jiang Q., Zhao W., and Xiong W., a research team from China examining the mediating role of SRL strategies between programming self-efficacy and CT (Li et al., 2025). A third cluster connects Liang J.-C., Tsai M.-J., and Hsu C.-Y., a Taiwanese group with a strong track record in CT assessment and measurement.

Two observations stand out from this network. First, no co-authorship links connect the three clusters. This finding must, however, be interpreted with caution rather than taken as direct proof that collaboration is organized exclusively along local lines. VOSviewer maps are threshold-dependent: the network was constructed using full counting with a minimum of three documents per author, so weaker ties and isolated co-authorships between researchers in different clusters, as well as links mediated by authors falling below the inclusion threshold, are excluded by construction. The absence of cross-cluster edges therefore indicates the absence of strong, repeated collaborative ties, not necessarily the absence of any contact whatsoever; a lower threshold would likely reveal a number of weak bridging links.

Importantly, this interpretation does not rest on this visualization alone. It is corroborated by an independent, threshold-free indicator: the international co-authorship rate for the corpus is only 14.58%, appreciably lower than the 23.1% reported by Riskawati et al. (2025) for CT in physics education. Because this metric is computed across all 38 articles and is unaffected by any mapping parameter, the convergence of the visual and the metric supports the conclusion that collaboration in this field remains predominantly bounded by national and institutional lines. This disparity may reflect the relative youth of SRL and CT as a distinct research area. Building international collaborative networks therefore represents both a tangible opportunity and an urgent necessity for future researchers, and a formal sensitivity analysis across a range of co-authorship thresholds would be a valuable extension of the present mapping.

RQ 4. What is the main research theme and how has it evolved over the study period?

Figure 3 presents a keyword co-occurrence network created in VOSviewer using the overlay visualization mode. Each node represents a keyword, with node size proportional to frequency of occurrence and color indicating the average year of publication. Because the co-occurrence threshold was set to two, the map retains a broad range of peripheral terms alongside the two dominant themes, with hue encoding the average publication year of each keyword; the scale runs from purple-blue (around 2020) through green (2022–2024) to yellow (2025).

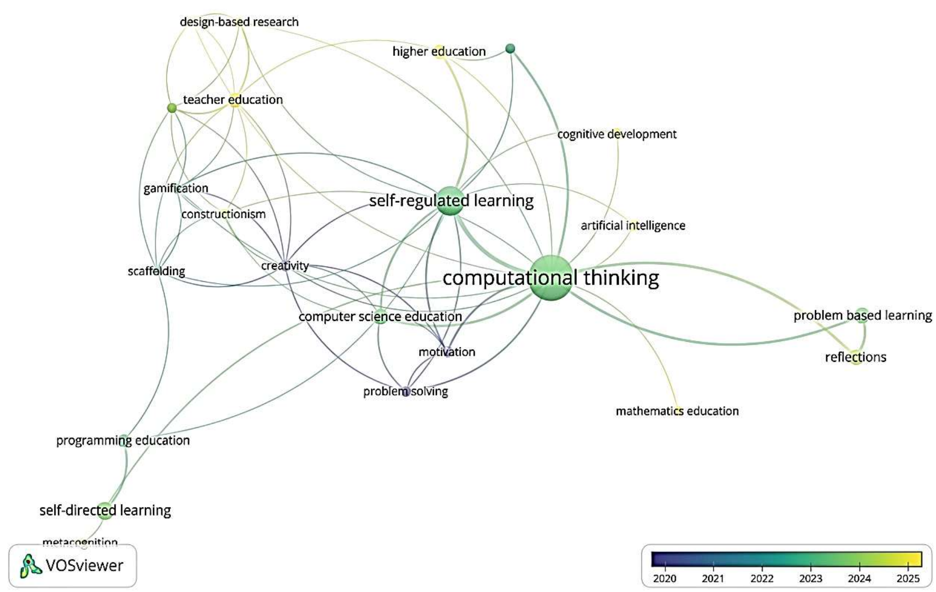

Figure 3. Keyword co-occurrence networks with overlay visualization (VOSviewer)

"Computational thinking" and "self-regulated learning" dominate the map: both are rendered in green and sit at the center of the densest region of links, with computational thinking the single largest node. Their size and central position confirm that the two constructs jointly anchor the field and are most strongly associated with one another. Clustered around them, and likewise in green (indicating consolidation during 2022–2024), are "computer science education", "programming education", "self-directed learning", "scaffolding", "gamification", "constructionism", "reflections" and "problem-based learning", the instructional and design vocabulary through which the SRL–CT relationship has been operationalized. The earliest terms, shown in purple-blue (around 2020–2021), are the foundational cognitive constructs "creativity", "motivation" and "problem-solving", which pre-date the recent surge. The most recent terms, in yellow (2024–2025), are "higher education", "artificial intelligence", "cognitive development", "mathematics education" and "design-based research", signaling a contemporary shift towards technology-mediated, AI-supported and discipline-specific applications, alongside a growing methodological interest in design-based research.

The same picture is supported by the frequency distribution that explains this network. The most common author keyword, by far, is "Computational thinking" (17%) (n=25); followed by "Self-regulated learning" (10%) (n=15); and, third, "Self-directed learning" (4%) (n=6), representing therefore more than 31 % of all occurrences of keywords in the corpus. The repeat co-occurrence of metacognition and scaffolding, along with SRL and CT terms, suggests some could carry theoretical importance: metacognition is the cognitive mechanism that effective self-regulation leverages (Zimmerman, 1989), while scaffolding is the most commonly used instructional strategy to develop meta-skills in programming contexts (Bonner et al., 2021; Gu et al., 2025).

Figure 4 presents the thematic evolution across three periods (2017-2021, 2022-2024, and 2025-2026). Rather than a purely qualitative flow map, the figure quantifies each transition: the width of every band is proportional to the number of shared keyword occurrences (n), and each band is labeled with its Weighted Inclusion Index (WII, a measure of thematic continuity expressed as a percentage) together with its share of the total inter-period flow.

During the first phase (2017-2021), the dominant theme was 'computational thinking' in

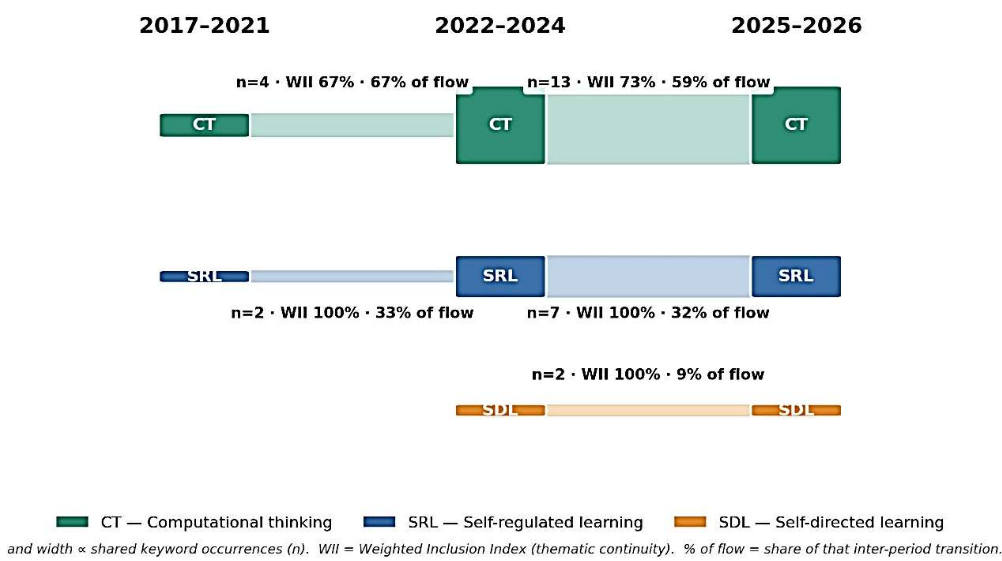

Figure 4. Thematic evolution of SRL and CT research (2017-2021, 2022-2024, 2025-2026)

its various forms. The research in this phase was primarily exploratory: elaborating the definition of CT in an educational context and investigating the inclusion of CT in curricula for STEM and CS disciplines. While self-regulation was discussed, it did not yet exist as an independent variable, only implicitly through discussions of self-directed learning, problem solving, and metacognitive processes in programming tasks.

In the second period (2022-2024), however, a striking transformation unfolded. Self-directed learning appeared for the first time as an independent thematic cluster, alongside computational thinking and self-regulated learning. Quantitatively, computational thinking carried the strongest continuity into this period (WII = 67%, n = 4), while self-regulated learning transferred with complete continuity (WII = 100%, n = 2). This interval coincides with a surge in empirical research viewing SRL not only as a contextual factor but also as an intervention variable (in an active and quantifiable sense), the effect of which can be causative for CT outcomes. Kong and Wang (2024), Gu et al. (2025), and Li et al. (2025) pair findings with established SRL instruments, each linking direct and mediated effects to CT skills.

The thematic map for the third period (2025-2026) shows reconsolidation but partial reconfiguration. Self-regulated learning has become the significant overarching theme, with strands from self-directed and computational thinking themes from the earlier period. Across the 2022-2024 to 2025-2026 transition, computational thinking again accounted for the largest flow (n = 13; WII = 73%; 59% of the inter-period flow), followed by self-regulated learning (n = 7; WII = 100%; 32%) and self-directed learning (n = 2; WII = 100%; 9%). Computational thinking remains prominent, but now as a core theme with specific links to programming education, scaffolding interventions, artificial intelligence-based and pedagogical agents (AI) learning platforms. This progression from articulating exploratory notions of conceptualization to more systematic empirical testing suggests maturation in the field, with theoretical coherence between SRL frameworks and CT measures.

Implications for Educational Practice

In addition to charting the intellectual structure of this field, the findings from this review also have practical implications for education. First, the consistently positive association between self-regulated learning and computational thinking indicates that SRL should not be treated as an additive disposition separate from programming or computational thinking, but rather as a core, explicit target for integrated classroom teaching within computation or programming curricula. This could be operationalized by embedding structured SRL supports (e.g., goal-setting routines, reflective programming journals, self-monitoring checklists, guided debugging prompts) directly into coding tasks, making the metacognitive processes that underpin algorithmic problem-solving visible and teachable (Gu et al., 2025; Kong & Wang, 2024).

Second, the prominence of scaffolding, artificial intelligence, and personalized learning environments among the last two or three thematic clusters suggests that technology-mediated SRL support is becoming core to effective CT instruction. Curriculum designers, instructional designers, and educational technologists can use intelligent tutoring systems and adaptive platforms providing just-in-time scaffolds that gradually fade until the learner is responsible for planning, monitoring, and evaluating their own computational work. Such designs are particularly beneficial in large or heterogeneous classrooms, where sustained provision of individualized teacher feedback is challenging.

Third, the validated CT assessment instruments identified in this corpus provide practitioners with reliable means of measuring learners' CT and of tailoring SRL interventions accordingly. In parallel, the co-design professional development models identified in this review underline the need to equip pre-service and in-service teachers with the pedagogical knowledge required to support self-regulation in computing classrooms. Finally, the marked under-representation of the Global South, and of Southeast Asia in particular, calls for context-sensitive curriculum development and for capacity-building initiatives in these regions. Ministries and teacher-education institutions in under-represented settings should not simply adopt SRL-CT instructional models developed elsewhere. However, they should commission local validation studies, including translation and cultural adaptation of SRL instruments and CT assessments, so the pedagogical benefits of integrating SRL and CT can be realized equitably across heterogeneous educational contexts.

Limitations of the Study

Several limitations should be borne in mind when interpreting the findings of this review. The first, and the most consequential, concerns the decision to construct the corpus from a single database. Scopus offers broad disciplinary coverage and highly consistent metadata. However, it is not exhaustive, and its coverage is uneven across the two literatures that this review brings together: educational research is comparatively well represented in ERIC and Web of Science, whilst computing education research is disproportionately published in IEEE and ACM venues, a substantial proportion of which is not indexed in Scopus. Three consequences follow. First, relevant empirical work on the SRL-CT relationship appearing exclusively in these outlets will not have been retrieved, so the corpus of 38 articles should be read as a Scopus-defined sample of the field rather than as its full population. Second, and more seriously for a bibliometric study, every performance indicator reported here the annual growth rate, the author and country productivity rankings, the source impact figures, and the 14.58% international co-authorship rate is computed within Scopus coverage and would in all probability shift were Web of Science, ERIC and IEEE Xplore records to be merged in, the ranking of leading journals and the relative positions of countries whose national outlets are unevenly indexed are particularly sensitive to this. Third, because database coverage is itself geographically skewed toward Anglophone and high-income publishing systems, the under-representation of the Global South documented in Table 5 is likely to be partly a coverage artifact as well as a substantive gap. The trends reported in this review are accordingly best understood as robust in direction but provisional in magnitude, and they should be corroborated through a multi-database replication before being treated as a definitive map of the field.

A second set of limitations concerns the eligibility criteria. The analysis was restricted to peer-reviewed journal articles written in English and published between 2017 and 2026. Conference proceedings, book chapters, dissertations, and non-English publications were therefore excluded, even though proceedings constitute a primary channel of dissemination in computer science education, and non-English outlets carry a considerable share of the educational research produced in the Global South. This introduces both a document-type bias and a language bias, and it compounds the geographical skew discussed above.

Third, the corpus was delimited by a Boolean string built around a fixed set of terms ("self-regulated learning", "SRL", "self-directed learning", "computational thinking", "algorithmic thinking"). Because terminology in this field is not standardized, conceptually relevant studies that describe the same constructs using different vocabulary will not have been retrieved. Concretely, studies operationalising self-regulation as “metacognitive regulation”, “self-monitoring”, “self-assessment”, “learning strategies” or “academic self-regulation”, and studies operationalising computational thinking as “computational problem solving”, “algorithmic problem solving”, “programming skills”, “coding competence” or “block-based programming”, fall outside the present search string even where the underlying constructs and findings are directly pertinent. A keyword-expansion procedure combined with forward and backward citation chaining would mitigate this and is recommended for future replications.

Fourth, whilst a final corpus of 38 articles is appropriate given the recency of the field, it limits the statistical robustness of several bibliometric indicators and the granularity of the thematic evolution analysis, particularly for the 2025-2026 period, which covers only a partial year (data collected in May 2026). Finally, as the quality appraisal demonstrated, most included studies rely on cross-sectional or short-term intervention designs and self-report measures of SRL, which constrains the causal claims that can be drawn from the synthesized evidence. None of these limitations invalidates the trends identified. However, each defines the interpretive boundaries within which the findings should be read and, in doing so, helps to set the agenda for the future research directions outlined below.

CONCLUSION

This study provides a framework for the research space between self-regulated learning (SRL) and computational thinking (CT), where the four axial categories from our research questions align into one answer. Using 38 articles published in niche journals including Education and Information Technologies this field has a steady annual growth rate of 24.14%, from just one article in 2017 to up to ten in its peak year of 2025, with citation impact led by Journal of Educational Computing Research, overwhelmingly these bibliometrics are bespeaking concentration in US/Taiwan/China (and only Indonesia is fairing less well here) leaving huge swathes of Southeast Asia and the rest of the Global South still greatly underrepresented. This co-authorship network decomposes into three autonomous clusters, with only 14.58% of collaborations international, confirming that partnerships remain bounded by national and institutional lines. At the same time, the theme map reveals a three-phase maturation of research: from exploratory definitions work on CT (2017-2021), through to SRL emerging as a directly measured construct (2022-2024), then culminating in a consolidation where SRL and CT are theorized to act reciprocally within AI-supported scaffolding-rich programming environments (in 2025-26). Future research should build on these findings with longitudinal, cross-national mixed-methods studies utilizing diverse databases and non-English language sources to go beyond mapping the SRL-CT relationship, through a robust international partnership that tests how self-regulation is educated to improve computational thinking.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the drafting of this manuscript, the authors used ChatGPT (OpenAI) and Claude (Anthropic) to refine sentence structure, improve grammar and readability, and check the consistency of reference formatting. Following the use of these tools, the authors reviewed and revised the content as necessary and accept full responsibility for the final content of the article.

Generative AI was not used to design the study, to construct or execute the search strategy, to screen or select articles, to extract, generate, or analyze data, to produce the figures and tables, or to formulate the interpretations and conclusions presented in this article. All figures were generated from the authors' own data using VOSviewer, Bibliometrix/Biblioshiny, and a reproducible analysis script provided in the Supplementary Files. No generative AI tool has been credited as an author or co-author.

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