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Beyond language teaching skills: How to cultivate computational thinking skills through computer-assisted language learning

Castledown

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Computational thinking (CT), often regarded as a core component of 21st-century digital skills, involves problem-solving skills developed through the use of Information and Communications Technologies (ICT). While CT has gained significant attention in science, technology, engineering, and mathematics (STEM) education, its potential within English Language Teaching (ELT) and Computer-Assisted Language Learning (CALL) remains underexplored. Addressing this gap, the present study investigates how English language teachers can foster CT skills through CALL-based instruction. Drawing on unstructured interviews with L2 Iranian teachers of English as a Foreign Language (EFL), the researchers employed both inductive and deductive content analysis to identify strategies for CT integration. These include fostering competitive learning environments, stimulating cognitive engagement across brain hemispheres, organising peer-reviewed activities, encouraging pattern recognition, and employing reverse problem-solving techniques. However, challenges such as limited CALL literacy, insufficient family support, and inadequate infrastructure were identified as barriers to effective implementation. This study contributes to the emerging intersection of CT and CALL by demonstrating that CT is not exclusive to STEM domains. It advocates for a pedagogical shift from traditional teacher-centred

methods to problem-solving approaches in language education and recommends the development of CT-informed CALL tools to better support teachers in cultivating students' computational thinking skills.

Keywords: computational thinking skills, 21st-century digital skills, 21st-century digital competency, English language teaching, applied linguistics

Introduction

In the 21st century, the widespread adoption of Artificial Intelligence (AI) and Information and Communications Technologies (ICT) has transformed nearly every aspect of modern life. From their homes, individuals are increasingly connected to their schools, colleges, or workplaces, and are therefore obliged to regularly interact with digital tools and systems. This technological proliferation has had a significant impact on education, reshaping both teaching practices and learning environments. However, the effectiveness of this innovation depends not only on access to technology but also on users' ability to meaningfully engage with them. This has led to a growing emphasis on developing what are often referred to as 21st-century digital skills (Van Laar et al., 2019).

Initiatives such as the Assessment and Teaching of Twenty-First Century Skills (ATC21S), along with frameworks promoted by the Organisation for Economic Cooperation and Development (OECD) and the European Union, have helped define and promote these skills (Rahimi, 2023; Rahimi & Sevilla-Pavón, 2025). Among these skills, computational thinking (CT) has been recognised as foundational. Originally rooted in computer science, CT involves the ability to break down problems, recognise patterns, abstract general principles, and design algorithmic solutions; skills that are increasingly seen as relevant across disciplines (Wing, 2006).

Science, technology, engineering, and mathematics (STEM) education has been at the forefront of this movement, with educators and policymakers advocating for the integration of CT and AI into K–12 curricula (Sun et al., 2021). Organisations such as the Computer Science Teachers Association (CSTA) and the International Society for Technology in Education (ISTE) have emphasised the importance of exposing students to CT skills from an early age (Rahimi & Sevilla-Pavón, 2025), a view that has been institutionalised through standards like the Next Generation Science Standards (NGSS, 2013). In response, many European countries have revised their national curricula to embed CT across educational levels, supported by new materials, digital tools, and AI-driven applications (Sun et al., 2021; Tang et al., 2020).

Recent research has explored how teachers can support CT development in learners. For instance, Tucker-Raymond et al. (2021) found that science teachers foster CT by encouraging collaboration, promoting independent problem-solving, and using diverse instructional resources. Similarly, Israel et al. (2015) showed that elementary educators can integrate CT into their classrooms through structured scaffolding and interdisciplinary collaboration.

While CT has often been viewed as exclusive to STEM fields, a broader perspective has begun to emerge. Wing's (2006) influential definition positions CT as a universal problem-solving process, relevant wherever structured reasoning and systematic thinking are needed. This perspective opens the door for CT to be applied beyond STEM, including in the humanities and language education (Kong et al., 2023; Valtonen et al., 2021). With the rise of AI-powered tools and conversational agents such as chatbots, the ability to approach problems computationally is becoming increasingly valuable in diverse learning contexts (Rahimi & Sevilla-Pavón, 2025).

Despite this shift, CT remains largely underexplored in the field of Computer-Assisted Language Learning (CALL), a field that focuses on the use of computers (including mobile devices) to enhance language teaching methods and improve learner engagement and outcomes (Beatty, 2013). Notable exceptions include Rahimi and Sevilla-Pavón, (2025), who applied and validated CT skills for the field of CALL, and its instrument for students within a virtual exchange context, highlighting how CT can influence language learners' attitudes and intention to use virtual exchange, as well as developing the theory of computational thinking competency for language teachers, and its corresponding scale. Moreover, Rahimi and Daneshvar Ghorbani (2025) developed the theory of language teachers' computational thinking competency in Computer-Assisted Language Learning (LTCCTCALL) and created a corresponding scale for language educators. However, they also identified a key challenge: many language educators lack the training and pedagogical strategies needed to cultivate CT skills within CALL environments.

Pioneers in the field of CALL have long emphasised the importance of adapting to emerging technologies and leveraging them to expand the potential of language learning (Colpaert, 2020; Gimeno-Sanz, 2015). In response to this call, the present study aims to bridge a critical gap by exploring how CT – one of the core competencies of the 21st century – can be meaningfully integrated into CALL pedagogies. In doing so, it contributes to a growing interdisciplinary dialogue and offers practical pathways for language educators to enrich their teaching with CT-based approaches.

Literature review

Computational thinking skills

The terms *computational thinking*, *computing*, and *computer programming* are often used interchangeably in educational discourse, leading to considerable confusion. To address this ambiguity, the International Society for Technology in Education ISTE provided a widely accepted definition of CT:

> Identifying problems in such a manner that a computer and other tools can be utilized to assist in logically solving them through algorithmic thinking, identifying, analyzing, and implementing possible solutions to achieve the most efficient and effective combinations of steps and resources; and

generalizing and extending this problem-solving process to a wide spectrum of problems. (Yadav et al., 2016)

This comprehensive definition has informed conceptual frameworks developed by researchers such as Korkmaz et al. (2017) and Tsai et al. (2020). They conceptualise CT as a multi-dimensional problem-solving process in which users leverage computers and digital tools to address challenges using creativity, algorithmic reasoning, critical thinking, collaboration, and strategic problem-solving.

Importantly, these scholars argue that CT is not confined to STEM disciplines but is applicable across diverse educational contexts. In line with this broader view, the present study adopts and adapts these CT components to the specific context of CALL. Accordingly, the framework for CT in this study includes the following five interrelated dimensions:

- Creativity, which refers to the ways English language teachers use CALL tools to encourage learners to creatively engage with and solve language-related challenges.
- Algorithmic Thinking, which involves guiding learners to break down language tasks into sequential steps, helping them systematically resolve learning problems through CALL environments.
- Critical Thinking, which encompasses strategies teachers use to prompt students to analyse and evaluate language issues using cognitive and digital resources available through CALL.
- Collaboration (Cooperativity), which highlights how teachers foster cooperative problem-solving, enabling students to collaboratively address linguistic tasks using CALL technologies.
- Problem-Solving, which relates to how educators support learners in identifying, testing, and applying effective strategies, mediated by CALL tools, to overcome language learning difficulties.

By embedding these computational thinking dimensions into language instruction, the study underscores how CALL can serve not only linguistic but also cognitive and digital skill development, preparing learners for the demands of 21st-century education.

Related studies

A growing body of research recognises the potential of CT to enhance students' analytical reasoning and problem-solving skills through the use of ICT and AI. These skills are seen as essential for fostering effective learning in the 21st century (Rahimi, 2023). As a result, researchers have actively sought innovative ways to integrate CT into language learning, leveraging digital tools and environments to support this goal (Bower et al., 2017; Rahimi & Sevilla-Pavón, 2025).

Recent empirical studies have applied this integration in practice. For example, Wu et al. (2024) conducted an experimental study aimed at cultivating CT skills among English language learners to improve their writing proficiency. The experimental group was trained in key CT components – decomposition, generalisation, abstraction, algorithmic thinking, and evaluation – while the control group received instruction through traditional methods. A combination of writing tasks, CT assessments, surveys, and interviews was used to collect data. Both quantitative and qualitative findings showed that the integration of CT into the English writing course significantly enhanced learners' writing performance and higher order thinking skills. CT enabled students to evaluate texts more critically, identify structural or conceptual issues, and apply creative strategies to improve their writing, demonstrating increased creativity and reflection in their work.

In a related study, Rahimi and Sevilla-Pavón (2025) introduced CT in CALL and designed the "CTCALL framework", along with a validated measurement scale. Their research aimed to enhance CT-related competencies, such as algorithmic thinking, abstraction, evaluation, generalisation, and collaboration, among Spanish EFL learners participating in virtual exchanges. In these exchanges, learners engaged in a range of collaborative and immersive tasks, including sharing cultural and historical information, participating in virtual reality museum tours, answering project-related questions, brainstorming, group work on final digital storytelling projects, and reflecting on personal traits. Findings from a bisymmetric analytical approach revealed that the CTCALL framework significantly influenced learners' acceptance of virtual exchange practices. In particular, students who employed abstraction (focusing on essential rather than extraneous information) and generalisation (transferring solutions from one task to another) demonstrated higher engagement and perceived alignment between the virtual exchange, their learning goals, and their individual competencies.

Further supporting the integration of CT into diverse educational contexts, Prado et al. (2021) conducted a comparative case study exploring how CT can be taught to exceptional learners in inclusive classrooms. Two teachers implemented CT strategies with mixed groups of English language learners, including students with disabilities and students identified as gifted. Using qualitative coding techniques, the study found that peer feedback, teacher modelling, questioning strategies, and group discussions were effective in fostering CT skills across a range of learner profiles.

Similarly, Yu et al. (2024) conducted a systematic literature review of 16 peer-reviewed journal articles that examined CT integration in language learning. Their findings revealed that tools such as educational robots and Scratch were among the most frequently used technological interventions. Moreover, they found that key CT components, particularly decomposition, abstraction, and generalisation, positively impacted learners' acquisition of foreign languages, especially in the areas of grammar and writing.

Collectively, these studies provide strong empirical support for the integration of CT into language education. They demonstrate that CT not only enhances linguistic competencies but also fosters transferable cognitive skills such as creativity, collaboration, and critical thinking; skills that are essential for learners navigating the demands of both language learning and digital literacy in today's educational landscape.

Literature gap and the purpose of the study

Although interest in the integration of CT into language education is growing, research in this area remains limited. Existing studies have primarily focused on the effects of CT on language learners' performance, attitudes, and skill development within English language teaching contexts (e.g., Rahimi & Daneshvar Ghorbani, 2025; Rahimi & Sevilla-Pavón, 2025; Yu et al., 2024). However, few have examined how teachers can actively engage students in CT through the use of CALL materials – a critical dimension given the increasing emphasis on 21st-century digital skills in education (Angeli & Valanides, 2020; Rahimi & Sevilla-Pavón, 2025).

This gap is particularly notable considering the growing consensus around the importance of integrating CT into CALL to enhance students' digital literacy, problem-solving abilities, and higher-order thinking skills (Rahimi & Daneshvar Ghorbani, 2025; Rahimi & Sevilla-Pavón, 2025). While the theoretical value of CT in CALL has been acknowledged, empirical studies exploring practical, teacher-led strategies for embedding CT into language learning remain scarce.

In response to this gap, the present qualitative study aims to investigate how EFL teachers can use CALL materials to promote computational thinking among their students. The study seeks to contribute to both theory and practice by identifying concrete pedagogical approaches and offering insights into teacher agency in fostering CT skills through technology-enhanced language instruction. To guide this inquiry, the following research question is proposed:
RQ: How can EFL teachers use CALL materials to engage their students in computational thinking

Methodology

Study design

In the context of growing interest in 21st-century competencies, CT has emerged as a leading area of inquiry in educational research (Rahimi & Sevilla-Pavón, 2025). Given the exploratory nature of this topic, particularly its integration into language education through CALL, this study adopts a qualitative research design. As Creswell (2014) suggests, qualitative approaches are especially appropriate for investigating relatively underexplored topics, enabling researchers to gain a deep understanding of complex phenomena. Furthermore, qualitative research is well suited to uncovering educators' perspectives on emerging instructional practices and pedagogical innovations (Creswell, 2014).

This methodology enables a rich, contextualised understanding of how teachers perceive and implement CT in their CALL practices. By centering participants' voices and experiences, the study offers insight into their beliefs, attitudes, and strategies, allowing the researchers to explore not just what teachers do, but how and why they engage learners in CT (Maxwell, 2022). Such depth is rarely attainable in quantitative approaches, which may overlook the nuances of educational settings, and the real-world challenges teachers face when integrating digital tools (Braun & Clarke, 2019).

To achieve these goals, the study employs a narrative inquiry within a descriptive design framework. This approach is particularly effective for investigating the current state of a phenomenon by capturing and analysing the lived experiences of participants (Edmonds & Kennedy, 2016). Narrative inquiry allows for a detailed account of teachers' journeys, providing both individual and collective insights into how CALL is used to foster CT skills in EFL classrooms.

Participants

Data collection was conducted during the summer and fall semesters of the 2021 academic year. The first author contacted a pool of 34 Iranian EFL teachers through email and WhatsApp, all of whom were personally known to him. The invitation clearly explained the purpose and procedures of the study to ensure informed participation. Out of the 34 teachers contacted, 23 agreed to participate.

To ensure rich and meaningful data, the study employed maximum variation sampling (Patton, 2002), a strategy designed to capture key dimensions of diversity across participants in order to deeply explore the target phenomenon in varied contexts. From the larger group, a final sample of 12 participants was purposefully selected based on this criterion. The sample included seven male and five female Iranian EFL teachers, all of whom had between one and seven years of language teaching experience.

Participants also varied in their familiarity with CALL tools. Specifically, three teachers had one year, five teachers had two years, and four teachers had three years' experience using CALL materials in their classrooms. Notably, several participants were recognised as leading figures in the local CALL community, with extensive use of both CALL and Mobile-Assisted Language Learning (MALL) technologies in their instructional practices.

All participants held postgraduate degrees in applied linguistics, comprising three PhD holders and nine with master's degrees. They taught English in a range of educational contexts, including major urban centres such as Tehran, Isfahan, and Kermanshah, as well as smaller cities like Nowshahr and Quchan, providing further variation in the institutional and regional contexts represented. Table 1 presents a summary of the participants' demographic and professional backgrounds.

Table 1. Participants' demographic information

Name	Gender	Age	Degree	City	Teaching experience (years)	Experience in CALL (years)
Morteza	Male	26	MA	Nowshar	3	2
Fatemeh	Female	32	MA	Isfahan	6	3
Samin	Female	32	PhD	Isfahan	7	3
Asma	Female	26	MA	Kermansha	1	1
Ali	Male	31	MA	Tehran	4	3
Reza	Male	31	MA	Quchan	5	2
Mozhgan	Female	39	PhD	Tehran	7	2
Malihe	Female	35	PhD	Tehran	5	2
Mohsen	Male	28	MA	Tehran	2	1
Nader	Male	29	MA	Tehran	3	1
Ramin	Male	27	MA	Tehran	2	2
Hamid	Male	29	MA	Quchan	3	3

Data collection procedure

To gather rich, in-depth data aligned with the study's exploratory aim, the researchers employed unstructured interviews, a method particularly well-suited for capturing participants' lived experiences, beliefs, and perspectives (Fusch & Ness, 2015; Merriam & Tisdell, 2015). As Creswell (2014) highlights, unstructured interviews allow researchers to explore emerging topics in depth, especially when few cases are selected for intensive investigation. This approach centres participants' voices and enables a nuanced understanding of their experiences with CALL and CT (Maxwell, 2022), while also revealing contextual insights not easily captured through quantitative methods (Braun & Clarke, 2019).

Before initiating data collection, the first author obtained written informed consent from all participants. The consent form outlined the study's purpose, participant selection rationale, and confidentiality assurances. To protect privacy, all participants were assigned pseudonyms in subsequent reporting.

Eleven interview questions were developed based on the study's conceptual framework. To ensure content validity, these questions were reviewed by three CALL experts and two STEM scholars. For face validity, the questions were also piloted with three teachers who shared characteristics with the target participants. Feedback confirmed that the questions were clear, relevant, and accessible.

Interviews were conducted via WhatsApp in one to three sessions, each lasting between 20 and 35 minutes. Participants were invited to choose their preferred language for the interview; all opted to speak in Persian, their first language, to foster a more relaxed and authentic exchange.

To ensure data saturation, the researcher applied four strategies:

1. Saturation Grid Method: A checklist of key topics and categories was used to monitor data coverage across interviews (Brod et al., 2009).
2. Probing and Epoché: Probing questions were used alongside a bracketing strategy (epoché) to elicit deeper insights (Bucic et al., 2010; as cited in Fusch & Ness, 2015).
3. Repetition Monitoring: Interviews continued until participants' responses began to repeat existing findings, indicating saturation (Saunders et al., 2017).
4. Ongoing Reanalysis: After each interview, data were transcribed and subjected to preliminary analysis. New codes and themes were tracked iteratively to determine whether additional interviews yielded new insights (Guest et al., 2006).

The data were analysed using thematic content analysis, a flexible method well suited for identifying patterns and themes related to the research question. The researchers applied a combination of deductive and inductive approaches, using MAXQDA (version 20.0) to organise and analyse the data (Kuckartz & Rädiker, 2019). This mixed approach allowed for both testing pre-defined categories derived from the literature (deductive) and uncovering unanticipated insights from the data (inductive) (Braun & Clarke, 2019).

The analysis followed Braun and Clarke's (2006) six-phase model for thematic analysis, adapted as follows:

1. Familiarisation: The first author transcribed all interviews, read and reread the transcripts, and developed an overall understanding of the dataset.
2. Initial Coding: Both deductive and inductive codes were generated. Deductive codes were based on the CT framework (adapted from Korkmaz et al., 2017; Tsai et al., 2020), while inductive codes emerged from participants' input outside the predefined framework.
3. Theme Development: Codes were grouped into broader themes based on conceptual relationships and recurrence across interviews.
4. Reviewing Themes: Relationships between codes and themes were reexamined to ensure internal coherence and alignment with the research objectives.
5. Refining Themes: The themes were named and organised visually through color-coded data maps to facilitate interpretation.
6. Validation and Inter-coder Reliability: To enhance the credibility of the findings, the complete coding process was reviewed by two independent experts (Patton, 2002).

Importantly, several inductively derived codes, such as lack of CALL literacy, infrastructure challenges, family support issues, classroom overcrowding, and limitations regarding Technological Pedagogical Content Knowledge (TPACK)[1], emerged during the analysis and were not part of the original CT framework. These findings provided additional insights and highlighted the contextual challenges faced by EFL teachers when implementing CT via CALL. The final themes and findings are presented in the following section. Figure 1 illustrates the step-by-step data analysis process.

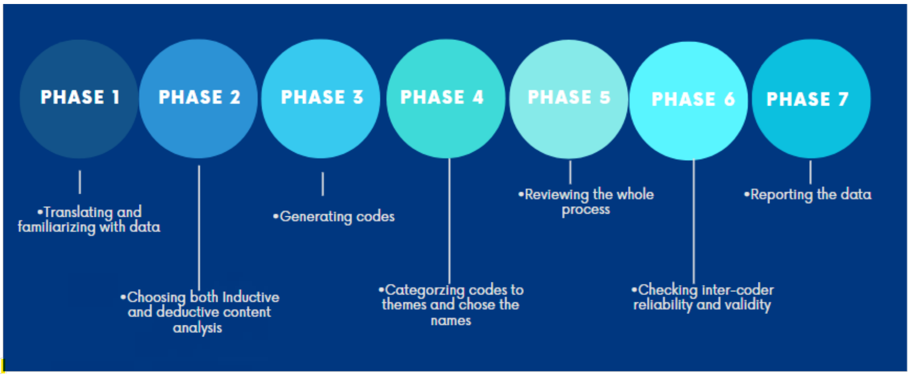

Figure 1. The process of data analysis adapted from Braun and Clarke (2006)

Trustworthiness. To ensure the rigor and reliability of the study, the researchers adhered to the four widely recognised criteria for trustworthiness in qualitative research proposed by Lincoln et al (1985): credibility, transferability, confirmability, and dependability.

Credibility was established by conducting interviews until data saturation was reached, as recommended by Saunders et al. (2017). This ensured that the information gathered was both consistent and reflective of participants' experiences. Additionally, in line with Fraenkel and Wallen (2006), data collection was extended across multiple sessions and contexts, enabling participants to elaborate their responses clearly and meaningfully. The iterative nature of the interviews and ongoing probing further contributed to the trustworthiness of the findings.

To enhance transferability, the study employed cross-case sampling (Ary et al., 2013). Participants were purposefully selected from diverse teaching contexts and educational levels, each with varying degrees of experience in implementing CALL. This diversity allowed the findings to be applicable to a broader range of EFL teaching settings and offered insights that other educators or researchers might relate to in similar environments.

Confirmability was addressed through a combination of strategies. First, two external researchers reviewed the coding and interpretation processes to reduce researcher bias and ensure objective analysis. Second, the study employed member checking (Creswell, 2014), inviting participants to review and validate the researchers' interpretations and thematic conclusions. Participants were asked to provide open-ended feedback on the reported findings, which was subsequently integrated into the final analysis to ensure alignment with their perspectives.

Finally, to establish dependability, the researchers implemented a saturation grid method (Brod et al., 2009), systematically tracking the appearance of key themes and objectives throughout the interviews. This process enabled the researchers to determine precisely when additional data collection ceased to yield new insights, affirming the stability and consistency of the findings over time. Together, these measures reinforced the methodological integrity of the study and ensured that its results were grounded in participants' authentic experiences, minimising bias and enhancing overall trustworthiness.

Findings

Thematic content analysis revealed how Iranian EFL teachers used CALL materials to cultivate various components of CT in their classrooms. These included algorithmic thinking, cooperativity, creativity, critical thinking, and problem-solving. However, participants also noted several barriers that limited their ability to implement CT effectively, such as technological constraints, pedagogical gaps, and institutional challenges. Below, each CT component is discussed in detail with supporting excerpts from teacher interviews.

Algorithmic thinking

Participants reported that algorithmic thinking was encouraged through activities that required students to break down complex language problems into smaller, more manageable steps. Teachers used deductive and inductive methods, scaffolding learning from basic grammatical rules to more advanced structures. For example, Ali explained: "I try to show the relationship between language components either deductively or inductively while solving their language activities." Morteza added: "They have to start from simpler processes such as solving some elementary grammatical rules and then move toward harder and advanced levels." Asma noted a categorisation strategy: "I ask them to divide their problems into special categories, i.e. grammar, comprehension, and specify a proper CALL material for each of them." However, some teachers struggled with guiding students through step-by-step solutions due to limited pedagogical knowledge in CALL. As Nader stated: "We play audio, and then we provide the learners with some sentences and ask them to check which one is true or false… But in terms of reading, speaking, writing, and grammar, I do not have any idea." Mohsen acknowledged the difficulty: "It is really difficult as it needs a high level of digital literacy and pedagogy as well."

Cooperativity

Data also revealed that teachers fostered cooperative learning through CALL by designing collaborative tasks and promoting peer review. These activities helped learners engage with each other and solve language tasks collectively. Samin shared the following: "Review sessions in Adobe Connect and completing the weekly projects are suggested to be done cooperatively." Additionally, Hamid remarked: "Some of the group activities with high quality are awarded and introduced in the class Telegram channel." Nader added: "I provide them with tasks, especially in the format of gap tasks that they must collaborate and discuss to achieve ultimate results."

Nonetheless, several teachers cited infrastructure limitations, large class sizes, and insufficient CALL training as obstacles. As Asma admitted: “I am not that competent in CALL… I do not know how to create a cooperative atmosphere in these situations.” Morteza emphasised: “If there are enough facilities like language labs connected to the net, it is possible. But in classes where the facilities are just for teachers, cooperation using CALL is meaningless.” Lastly, Samira observed: “It’s challenging since many learners don’t follow these programs, and we struggle with collaborative task design due to poor internet and limited parental support.”

Creativity

Teachers employed various strategies to enhance learners’ creativity using CALL, including authentic materials, flipped classrooms, gamification, and student-created content. Many emphasised the importance of meaningful tasks that mirrored real-world communication. As Asma explained: “Providing authentic materials for listening and reading can be effective as it presents real-world challenges that learners face in the target context.” Also, Morteza suggested: “Creating an English teaching website covering all language skills would be an excellent idea where learners solve their language activities using their imagination.” Additionally, Malihe noted: “I use meaningful practice over mechanical drills. For example, I use Google Maps in class and ask learners to describe locations using grammar rules.” Gamification was another common technique. In this respect, Reza pointed out: “You can integrate games into your lessons, web-based ones, that are fun and improve learners’ imagination.” Furthermore, Fatemeh highlighted the role of extrinsic motivation: “To motivate them, I create competition where the more learners produce instructional content, the more points they earn,” whilst Mozhgan added: “They can find speaking partners on online platforms and solve their language problems by sharing ideas.”

Critical thinking

To promote critical thinking, participants designed complex tasks that required learners to analyse, synthesise, and reflect using CALL tools. Techniques included using unfamiliar texts, encouraging metacognitive reflection, and introducing time constraints. In this respect, Morteza stated: “While doing their tasks with CALL, I ask them to explain how they solved academic challenges.” Malihe also shared her technique: “I give them a text with many difficult words and ask them to work with online dictionaries. It gives them the courage to explore and move forward.” Additionally, Fatemeh emphasised task sequencing: “A meaningful sequence of activities helps with student progression,” whilst Ramin stated that: “Engaging students in activities involving skills and subskills activates both brain hemispheres and reduces passivity.” Samin contributed by stating: “I design challenging activities and ask them to search for CALL materials related to classroom tasks.” Ali, on the other hand, noted the impact of time pressure: "Adding time limitations while using CALL materials makes the task more cognitively engaging." And Samira discussed engagement beyond the classroom: "I try to engage students inside and outside class by sharing slides, movies, and booklets on a channel aligned with their language activities."

Problem-solving

Participants described various problem-solving strategies used with CALL, including listing, categorising, guessing and checking, pattern recognition, and working backward. In this respect, Samin explained: "I teach students to list and categorise their language problems, then find the appropriate CALL tool for each one." On the other hand, Ali described a structured approach: "I tell them to guess the answer, check it using CALL tools, and revise it accordingly," whilst Malihe explained: "I develop a practical syllabus for each class and guide students through analysing and completing assignments using CALL." On the other hand, Samira used reverse sequencing in a creative task: "I show a video, like baking a cupcake, and ask students to guess the steps or work backward from the final product."

However, several teachers reported barriers to implementing problem-solving strategies via CALL, such as large class sizes, digital inequality, lack of family support, and technical constraints. Reza remarked: "It's difficult when you have many students from different backgrounds," and Fatemeh added: "It depends on learners' age, tech knowledge, and access to devices." Ali noted: "Some students don't have their own devices and use their parents' phones, which aren't always available." Furthermore, Asma pointed out: "It's time-consuming and requires extra energy, but the teacher must take responsibility." Additionally, Nader admitted limited technical expertise: "If the problem is related to Word or PowerPoint, I can help. Otherwise, I can't offer much support." Figure 2 illustrates the thematic map derived from the content analysis, which provides a visual representation of the primary themes identified.

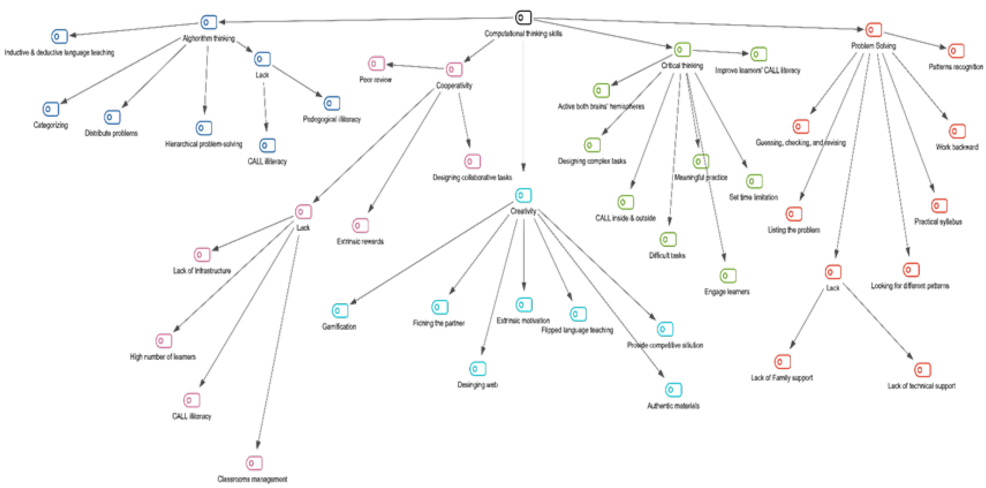

Figure 2. The thematic map codes

Figures 3 and 4 show the code frequency for both code segments, and the sub codes. As shown in Figure 3, Critical Thinking emerges as the most emphasised CT skill, represented by a dark blue bar at 38%, followed by cooperativity and creativity, each at 20%. Algorithmic thinking is shown at 12%, while problem-solving ranks the lowest at 10%. Moreover, Figure 4 displays sub codes segments where engaging learners with CALL tools, as well as providing difficult language tasks with CALL are among the most frequent sub themes, while lack of pedagogical infrastructure" follow closely behind.

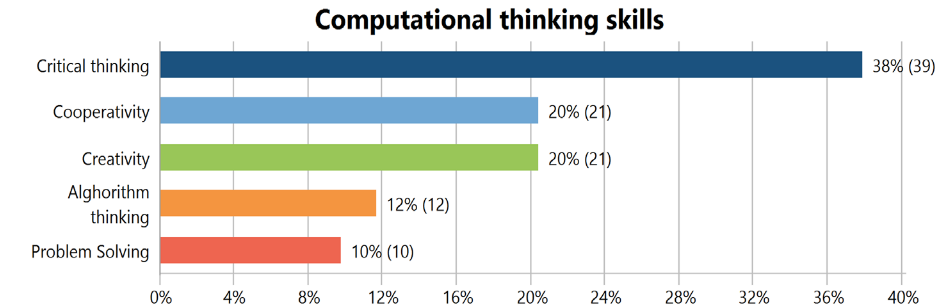

Figure 3. The frequency of CT factors

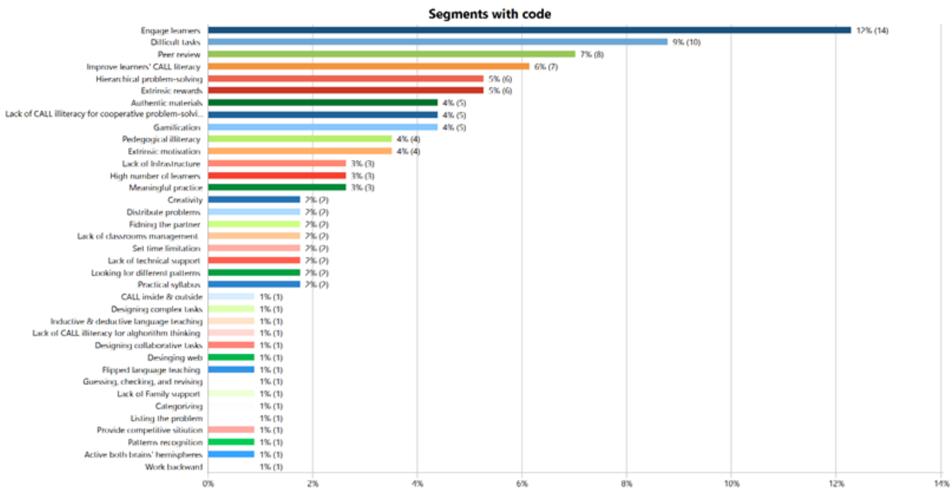

Figure 4. The frequency of CT factors' subcodes

Discussion

This study explored how Iranian EFL teachers engage learners in CT through the use of CALL materials, focusing on five core CT components: algorithmic thinking, cooperativity, creativity, critical thinking, and problem-solving. The findings confirm and extend prior research while also revealing important contextual challenges and implications for practice.

Algorithmic thinking

The analysis showed that teachers fostered algorithmic thinking by using deductive and inductive approaches to guide learners in understanding language rules and solving tasks step by step. Teachers helped students identify grammar patterns, decompose problems, and build solutions sequentially, key characteristics of CT. This supports previous findings by Israel et al. (2015), who demonstrated that deductive and inductive instruction fosters metacognitive awareness in CT development. Similarly, Sun and Wang (2003) found that CALL materials can scaffold learners' cognitive growth when combined with these teaching methods.

This finding also aligns with Rahimi and Sevilla-Pavón (2025), who reported that algorithmic thinking, through sequential task completion in virtual environments, enhanced learners' acceptance of virtual exchanges. Furthermore, teachers in this study organised linguistic problems into categories (e.g., grammar, comprehension) and recommended specific CALL tools for each category, an approach consistent with the decomposition principle of CT (Angeli & Valanides, 2020).

However, some teachers struggled to foster algorithmic thinking due to limited pedagogical knowledge and CALL literacy, mirroring the concerns raised by Butler and Leahy (2021) about the relationship between digital-pedagogical competence and CT integration. These barriers are widely acknowledged in both global and Iranian CALL literature (Aljohani, 2024; Hedayati & Marandi, 2014).

Cooperativity

The study found that teachers promoted cooperativity by designing collaborative CALL tasks, encouraging peer review, and integrating group-based activities. Learners were prompted to explain how they solved tasks, which fostered metacognitive dialogue and shared learning, key conditions for CT development. This finding echoes research by Hsu and Liang (2021) and Jacob and Warschauer (2018), who emphasise the role of collaboration in cultivating CT.

This also aligns with Rahimi and Sevilla-Pavón (2025), who reported that collaborative virtual exchanges improved learners' engagement with CALL and increased their intention to use these tools. Similarly, collaboration in CALL has previously been linked to enhanced learner attitudes (Rahimi, 2023), creativity (Hsu, 2019), and autonomy (Kessler & Bikowski, 2010). This study extends those benefits to the domain of CT development.

Nevertheless, some teachers were unable to foster cooperativity due to a lack of infrastructure, CALL literacy, and classroom management challenges. These findings are consistent with studies that identified the absence of adequate facilities and teacher training as major barriers to CALL integration in the Iranian context (Dashtestani & Hojatpanah, 2022; Taghizadeh & Ejtehadi, 2021). Similarly, Perrotta (2012) emphasised that classroom management is essential for integrating digital tools effectively.

Creativity

Participants described numerous strategies to enhance creativity using CALL, such as incorporating authentic materials, gamified activities, flipped learning, and student-generated content. Authentic materials, in particular, enabled learners to interact with language in real-world contexts, promoting deeper engagement and contextual problem-solving. This finding supports Rahimi and Sevilla-Pavón (2025), who emphasised the role of authenticity in fostering 21st-century skills.

Gamification was also seen as effective in increasing learner engagement and imagination, confirming earlier findings that games in CALL can reduce anxiety (Yang et al., 2022), increase willingness to communicate (Jia et al., 2023), and support vocabulary learning (Roohani & Heidari Vincheh, 2021). The current study extends this by showing that games can activate CT processes such as pattern recognition, abstraction, and problem decomposition, especially when used in competitive contexts (Min & Kim, 2021).

Flipped learning emerged as another impactful approach, providing opportunities for learners to engage in problem-solving both inside and outside the classroom, as advocated by Rezaeyan et al. (2025). This supports Zou et al. (2019), who found that flipped learning improves higher-order thinking skills. Teachers also developed language webs and creative syllabi integrating CALL across receptive and productive skills, echoing Kuo et al. (2012), who showed that web-based teaching promotes problem-solving.

Furthermore, teachers motivated learners by assigning extrinsic rewards, such as content creation competitions. This aligns with Parsazadeh et al. (2020) and Stewart et al. (2021), who found that motivation is critical to CT acquisition. Encouraging learners to seek language partners on online platforms also reflected the constructivist and interactionist foundation of creativity and CT (Marcelino et al., 2018; Rahimi & Sevilla-Pavón, 2025).

Critical thinking

Teachers fostered critical thinking by engaging students with challenging tasks, activating both brain hemispheres, and encouraging self-reflection using CALL materials. These techniques align with Durak and Saritepeci (2018) who found that digital engagement enhances learners' CT and reflective abilities. The use of real-world challenges and minimal teacher feedback pushed learners to think independently.

In this context, modelling, rather than correction, was a strategy to encourage learners to find their own solutions – consistent with findings from Prado et al. (2021) and Marcelino et al. (2018). Additionally, integrating time constraints and encouraging search-based tasks increased learners' engagement and problem-solving capabilities.

The findings suggest that CALL supports whole-brain learning, activating cognitive regions associated with CT, as confirmed by Xu et al. (2021), who found that CT development is linked to activation in the posterior parietal and frontal cortex. Teachers also encouraged learners to use CALL both inside and outside the classroom, increasing exposure and reflection; two key ingredients for developing higher-order skills.

Problem-solving

The study found that teachers explicitly taught problem-solving strategies using CALL, such as listing, categorising, pattern recognition, guessing and checking, and working backward. These strategies enabled learners to become more independent and confident in navigating language tasks. This echoes Rahimi (2023), who observed that technology has shifted the role of language teaching from delivering content to facilitating problem-solving.

Participants who taught students to organise tasks by difficulty level, language skill, and task type allowed them to match problems with appropriate CALL tools, accelerating both problem-solving and CALL literacy. These results support the recommendations of Jacob and Warschauer (2018), who proposed a correlation between media literacy, language literacy, and CT skills.

Pattern recognition, in particular, was highlighted as central to CT development, consistent with findings by Korkmaz et al. (2017) and Tsai et al. (2020). It was also identified as the most influential factor in learners' acceptance of virtual exchanges in Rahimi and Sevilla-Pavón (2025)

The strategies of guessing, checking, and revising were also emphasised. This aligns with Tucker-Raymond et al. (2021), who argued that learners must be comfortable making and correcting mistakes to foster CT. The backward problem-solving technique, in which learners work from the solution to the problem, was also used, agreeing with Kuzle (2019), who associated this strategy with heuristic thinking and real-world task transfer.

However, some participants noted that technical limitations, lack of family support, and insufficient time hindered their ability to develop learners' CT through CALL. These findings are consistent with prior research on the importance of both technical infrastructure and home support for CALL effectiveness (Hedayati & Marandi, 2014; Taghizadeh & Ejtehadi, 2021; Wang et al., 2021).

To conclude the discussion, this study confirms that CALL, when strategically applied, can be a powerful medium for cultivating CT in language education. However, it also highlights systemic barriers, such as infrastructure gaps, digital literacy deficits, and contextual constraints, that must be addressed for successful implementation. By integrating CT into CALL pedagogy, language educators can prepare learners not only for academic success but also for active participation in digitally mediated societies. These findings support ongoing calls for CT integration in language curricula (Rahimi & Daneshvar Ghorbani, 2025; Rahimi & Sevilla-Pavón, 2025) and offer practical insights for teacher training, curriculum design, and policy development. Table 2 illustrates a visual summary of the CT components taking into account the strategies and challenges pointed out in this section.

Table 2. CT components in CALL-based EFL instruction

CT component	Algorithmic thinking	Cooperativity	Creativity	Critical thinking	Problem solving
Strategies	Deductive/ Inductive methods Problem breakdown CALL tool matching	Peer review Group tasks Collaborative CALL use	Authentic content Gamification Flipped learning Creative outputs	Challenging tasks Timed activities CALL in/ outside class	Problem listing Pattern use Guess-check-revise Backward decision
Challenges	Low CALL literacy Weak pedagogy	Poor infrastructure Large classes Low CALL skills	Low motivation Limited authentic input	Tech gaps Unequal access	Lack of support Limited time devices

Conclusions and implications

The integration of CT into education, particularly language education through CALL, has gained increasing attention (Rahimi & Daneshvar Ghorbani, 2025; Rahimi & Sevilla-Pavón, 2025). Teachers play a pivotal role in embedding CT into their pedagogical practice, equipping students with the essential skills of the 21st century (Butler & Leahy, 2021). Responding to this call within the humanistic disciplines of ELT and CALL, this qualitative study investigated how Iranian EFL teachers can engage learners in CT through CALL materials.

The findings revealed a diverse range of methods, strategies, and techniques that teachers use to embed CT within their instruction. These included inductive/deductive teaching, gamification, flipped learning, categorisation, pattern recognition, and problem-solving techniques. However, several barriers such as limited CALL literacy, inadequate TPACK, and infrastructural constraints were also identified. The study thus holds significant theoretical and practical implications for researchers, curriculum designers, teacher educators, and policymakers.

Theoretical implications. This study makes several theoretical contributions:

1. Extending CT beyond STEM: While CT is traditionally associated with STEM, robotics, and programming, this study demonstrates its relevance and applicability in humanistic disciplines, particularly in language education and CALL.
2. Reframing CALL: The study reframes CALL not only as a tool for language instruction but also as a platform for developing digital-era cognitive skills, shifting the focus from “teaching with technology” to “teaching thinking with technology.”
3. Responding to emerging recommendations: The findings answer calls from scholars such as Rahimi (2023) and Rahimi and Daneshvar Ghorbani (2025) as well as Rahimi and Sevilla-Pavón, (2025) to integrate

CT into language education and support the vision advanced by pioneers in CALL (Colpaert, 2020; Gimeno-Sanz, 2015).
4. Foundation for future research: This study lays groundwork for further empirical and conceptual investigations into CT in CALL, encouraging researchers to expand the field's theoretical landscape.

Practical contributions. From a practical standpoint, the study identifies concrete steps that stakeholders can take to integrate CT into language education:
1. Designing CT-integrated CALL applications: Unlike STEM, where applications like Scratch and CodeMonkey are widely used to foster CT, ELT still lacks comparable tools. CALL developers and educational technologists are encouraged to design language-specific applications that support both linguistic development and CT skill acquisition.
2. Equipping teachers with pedagogical tools: Teachers should be trained in how to:
– Incorporate CT through language teaching methods (e.g., inductive/deductive, flipped learning).
– Use CALL for active, brain-engaging tasks.
– Apply CT strategies like decomposition, backward design, and pattern recognition.

Workshops and training programs should aim to enhance CALL literacy, TPACK, and CT-related pedagogy.
3. Reforming teacher education and recruitment: Teacher recruitment processes should consider competences in CT integration alongside language proficiency and teaching experience. Curricula in teacher education programmes should include modules on how to develop algorithmic thinking, abstraction, evaluation, and generalisation in the context of ELT.
4. Curriculum and policy development: Curriculum developers should align national language curricula with global frameworks such as the CSTA, the ISTE, ATC21S, OECD, and EU recommendations for CT in education. Integration of CT into language learning objectives will require updated syllabi, learning materials, and assessment criteria.
5. Institutional and family support: Government and educational authorities should allocate resources to:
– Improve school infrastructure and internet connectivity.
– Ensure equitable access to CALL materials for all learners.
– Encourage family involvement in students' out-of-class CALL engagement.
6. Shifting teaching paradigms: Language educators should transition from teacher-centred to problem-based learning approaches. By creating cognitively demanding, real-world tasks, teachers can help students become independent language users and thinkers.

Limitations and directions for future research

While the findings offer valuable insights, several limitations should be acknowledged. On the one hand, the use of goal-directed sampling and a relatively small sample size limits the generalisability of the findings. Future studies should consider randomised or stratified sampling techniques to enhance representativeness. On the other hand, the study was conducted exclusively within the Iranian EFL context. To gain a more global understanding, similar studies should be conducted in other EFL/ESL contexts. Lastly, the study employed a narrative-descriptive qualitative design. Future research could adopt a mixed-methods approach, grounded theory, phenomenological, case study, or ethnographic designs to deepen and diversify understanding of CT in CALL.

Despite these limitations, the study described here contributes to a growing body of literature advocating for a paradigm shift in language education; one that not only prepares learners for language proficiency but also for cognitive agility, digital literacy, and future-ready thinking. By integrating CT into CALL, educators can transform their classrooms into spaces where language and logic meet, fostering holistic, 21st-century learners.

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Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author upon request.

Declaration of generative AI in scientific writing

The authors in the current study did not use any kinds of artificial intelligence in any parts, and sections of the article.

Notes

1. TPACK is an educational framework that highlights the intersections between technology, pedagogy, and content for the effective integration of technology into teaching (Mishra & Koehler, 2006).

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