EXPLANATIONS OF GENDER EFFECTS ON LEARNING COMPUTATIONAL THINKING IN MATHEMATICS: A LITERATURE REVIEW

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This literature review examines gender-specific effects on learning computational thinking (CT) in mathematics education. It analyzes thirteen intervention studies with respect to the direction of gender effects and attributional patterns. Results show inconsistent findings: most studies report no gender effects, some report gender effects favoring boys, and one reports an effect favoring girls. Furthermore, the review reveals that studies finding no gender differences mainly use external attributions, while those favoring boys rely on internal attributions; the single study favoring girls uses both. The findings underscore the potential of well-designed interventions to reduce gender disparities in CT and the need for more detailed research.

INTRODUCTION

Computational thinking (CT) is increasingly recognized as a key 21st-century skill and is therefore being integrated into education. Mathematics offers a particularly suitable context for this integration, as CT can be meaningfully linked to both process-related and content-related aspects of the subject (Nordby et al., 2022; Tamborg et al., 2022). At the same time, both mathematics and computer science, which is the disciplinary root of CT, remain gender-segregated domains (e.g. Kennedy et al., 2025; OECD, 2023). Accordingly, the integration of CT into mathematics education raises questions about potential gender-specific effects. Previous studies on CT interventions report mixed outcomes, yet systematic research explicitly addressing gender differences in CT within mathematics education is still limited. Against this background, the present study aims to map and analyze how gender-specific effects in computational thinking interventions within mathematics education are explained in the literature, with a particular focus on the attributional patterns (Weiner, 1985) employed by authors.

THEORETICAL BACKGROUND

Computational Thinking in Mathematics Education

In the 1980s, CT emerged—primarily through LOGO programming—as a means for learners to construct and engage with computational representation of mathematical ideas and thereby construct new knowledge (e.g. Papert, 1996). Current notions of CT are usually broader and consider CT as the thought processes involved in formulating problems and solutions in an algorithmic manner (Grover & Pea, 2013; Kallia et al., 2021). This idea of CT is growingly considered as a fundamental skill, which all students should learn (Grover & Pea, 2013; Tamborg et al., 2022). Again, CT is therein

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connected to mathematics with conceptual overlaps, for example in algorithms or modelling (Kallia et al., 2021; Tamborg et al., 2022). Due to overlapping concepts and competencies, an integration of CT into mathematics education seems natural (Tamborg et al., 2022). Additionally, such integration is widely shown to be able to benefit mutual learning of CT and mathematics, though the explicit means are not yet fully understood (Kallia et al., 2021). When considering CT as a potential learning goal in mathematics classrooms, understanding gender-specific effects on learning outcomes is necessary to design equitable learning environments, enabling all students to acquire CT (Grover & Pea, 2013).

Gender in Mathematics Education and Computational Thinking

Gender differences arise primarily through socialization processes and frequently disadvantage women in many fields (Devi et al., 2024). Despite formal commitments to equal opportunities in learning mathematics, substantial disparities in learning outcomes persist (Gildehaus, 2024). Large-scale assessments consistently document this pattern: for example, in the 2022 PISA study, 15-year-old boys consistently outperformed girls (OECD, 2023) and a recent French longitudinal study showed that boys surpassed girls after only four months of schooling, with the gap widening over time (Martinot et al., 2025). These gender differences can also be observed in CT: In ICILS 2023, eighth-grade boys showed a small but significant advantage in overall CT performance with considerable cross-national variation (Kennedy et al., 2025). A review by Lin and Wong (2024) concluded that findings on gender differences in CT are inconsistent, highlighting the need for further attention (Lin & Wong, 2024). Existing explanations regarding gender differences in CT and mathematics education typically distinguish between internal factors (e.g., attitudes, beliefs, self-concept, and self-efficacy) and external factors (e.g., parents' and teachers' influences through stereotype activation; Gildehaus, 2024; Martinot et al., 2025; Zhang & Wong, 2024). This distinction corresponds with Weiner's (1985) Attributional Theory, which conceptualizes "perceived causes of success or failure" (p. 549). A central dimension of his framework is the *locus* of causality, differentiating between internal and external attributions, and thus offering a systematic way to analyze how learners' performance is explained (Weiner, 1985).

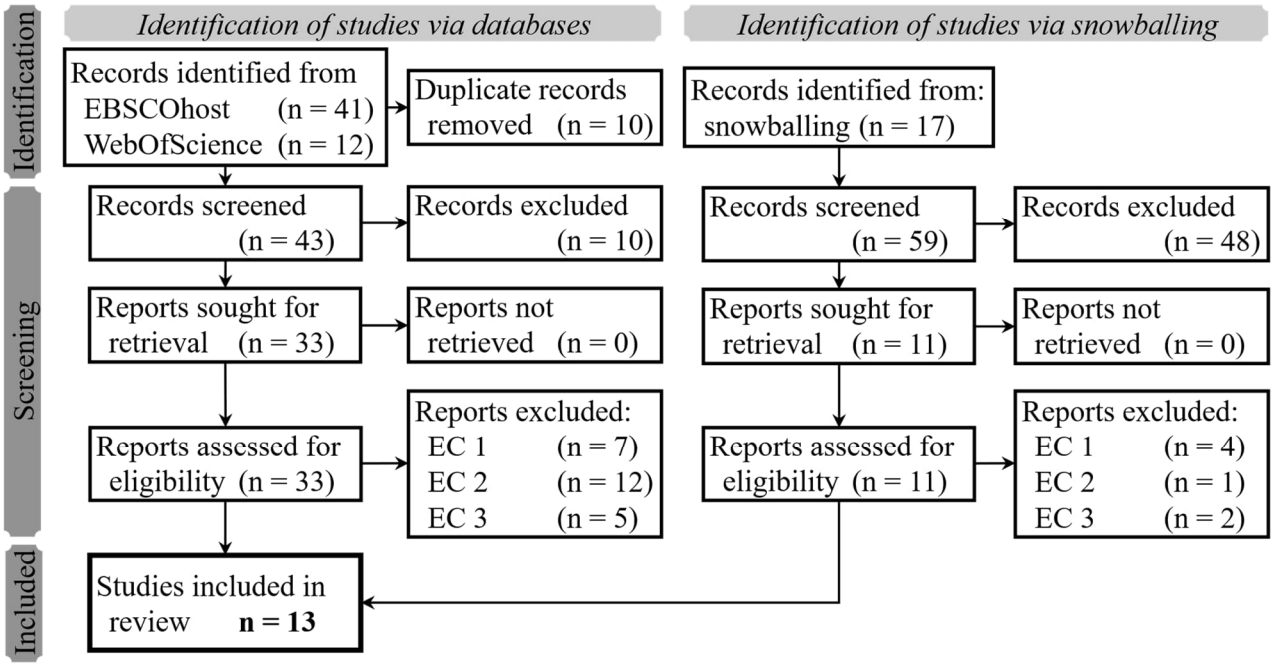
Our current study

To address the identified research gap, this study aims to systematically map and structure gender-related influences on learning CT within the context of mathematics education, drawing on Weiner's attribution theory (1985). As shown in earlier work, integrating CT into mathematics education is both feasible and beneficial. However, despite growing interest in CT, little is known about how gender-related factors shape students' engagement and performance when CT is embedded and specifically targeted in mathematics learning. Accordingly, the guiding research question of this paper is: *Which attributional pattern do authors use when explaining gender-specific effects in computational thinking interventions within mathematics education?*

METHODS

To this end, we conducted a systematic literature review of studies examining gender effects following a CT intervention within mathematics education. The review aimed to identify both the direction of gender effects and the psychological explanatory patterns used to account for gender differences in learning CT within mathematics education. The systematic literature search (Figure 1) combined database searches with subsequent snowballing based on reported gender effects in included studies.

Figure 1: Flowchart of the systematic search for documents



Study selection followed predefined inclusion and exclusion criteria (Table 1), which were partly adapted from comparable reviews (e.g. Lin & Wong, 2024) The papers were analyzed along several dimensions, including gender effects on CT and proposed explanations. To ensure intersubjectivity, each paper was coded independently by two researchers, and disagreements were resolved through discussion to reach consensus.

Table 1: Inclusion criteria and exclusion criteria used in the review

Inclusion Criteria (IC)	Exclusion Criteria (EC)
IC 1: Study investigates gender differences in learning CT	EC 1: CT education is topic, but no discussion or analysis of gender (effects) is provided.
IC 2: Study describes a mathematical didactic activity in which CT is a learning goal and presents results of this evaluation.	EC 2: Article does not present an empirical intervention study or CT is not a learning goal.
IC 3: Study is peer-reviewed and written in English	EC 3: Addresses research topic unrelated to the focus of the review

FINDINGS

A total of 13 intervention studies that investigated the effects of gender on developing students' CT in the context of mathematics education were included in this review. The majority of seven studies found no post-intervention gender differences in students' CT level, one study found a gender gap in favor of girls, and five studies found boys outperforming girls (see Table 2). However, two of the latter demonstrated low effect sizes or a greater growth in CT learning for girls, thereby reducing the existing gender gap (del Olmo-Muñoz et al., 2022; Polat et al., 2020). Across the analyzed studies, several explanatory mechanisms accounting for the presence or absence of gender differences were identified (see Table 2, right columns). These mechanisms can be systematically organized according to the *locus* dimension of Weiner's (1985) Attribution Theory. We synthesized four dimensions of internal attributions: Attitudes and behavior (I1), cognitive abilities (I2), mathematical abilities (I3), and motivation (I4). For external attributions, authors argue that effects are due to the four dimensions of a gender-fair measuring instrument (E1), gender friendliness of the intervention or tools (E2), the mathematical context (E3), and teachers' gender biases (E4).

Table 2: Directions as well as internal and external explanations of gender differences

		Explanations of effects	
Effect	**Study**	Internal[a]	External[b]
None	Angeli & Valanides, 2020		E2
	Atmatzidou & Demetriadis, 2016		E1
	Gökçe & Yenmez, 2023	I4	E2
	Jiang & Wong, 2022		E2
	Paucar-Curasma et al., 2023	I1, I4	E2
	Piedade & Dorotea, 2022		
	Tan et al., 2021		E2
In favor of girls	Plangg & Fuchs, 2022	I1, I2, I3, I4	E2, E3
In favor of boys	Angeli & Georgiou, 2023	I3	E2
	del Olmo-Muñoz et al., 2022	I1	
	Guggemos, 2021	I1, I4	
	Polat et al., 2021	I1, I3	
	Sung et al., 2023	I1	E2, E4

[a]*I1: attitudes & behavior, I2: cognitive abilities, I3: mathematical abilities, I4: motivation*
[b]*E1: gender-fair measuring instrument, E2: gender friendliness of intervention or tools, E3: mathematical context, E4: teachers' gender biases*

Synthesized cross-study insights into explanatory patterns

Attitudes and behavior (I1): This was frequently reported as contributing to boys' higher CT levels after intervention. Girls' lower CT self-concept (Guggemos, 2021), interest (Polat et al., 2021), general beliefs and attitudes (del Olmo-Muñoz et al., 2022), and their interactions with educational robots (Sung et al., 2023) were commonly cited. By contrast, girls' greater perseverance, and their ability to organize and collaborate effectively were used to explain effects favoring girls (Plangg & Fuchs, 2022) or the absence of significant gender differences (Paucar-Curasma et al., 2023).

Mathematical abilities (I3): Mathematical abilities were cited as explanatory factors for both effects favoring girls (Plangg & Fuchs, 2022) and boys (Angeli & Georgiou, 2023; Polat et al., 2021). In particular, geometry as a context appeared either beneficial (Plangg & Fuchs, 2022) or disadvantageous for girls (Angeli & Georgiou, 2023).

Motivation (I4): Lower motivation among girls in computer science was used to explain boys' higher CT levels (Guggemos, 2021). Conversely, interventions and programming tools that motivated and engaged all students were used to explain both non-significant gender effects (Gökçe & Yenmez, 2023; Paucar-Curasma et al., 2023) and higher CT levels in girls (Plangg & Fuchs, 2022).

Gender friendliness of interventions or tools (E2): Studies showing effects favoring girls (Plangg & Fuchs, 2022) or no significant effects were often explained through gender-friendly interventions or tools. In the latter case, this included gender-friendly programming tools and interventions (Angeli & Valanides, 2020; Gökçe & Yenmez, 2023; Jiang & Wong, 2022; Paucar-Curasma et al., 2023; Tan et al., 2021) or assessments (Atmatzidou & Demetriadis, 2016). Effects favoring boys were attributed to the use of non-gender-friendly educational robots (Sung et al., 2023).

DISCUSSION AND CONCLUSION

While our effect-related results are, in line with earlier research, inconsistent (Lin & Wong, 2024), they nonetheless reveal an underlying pattern: when an intervention yields outcomes favoring boys—an effect generally expected given established gender gaps in mathematics and CT (e.g. Kennedy et al., 2025)—authors typically explain these results through internal attributions. In this line of reasoning, gender-stereotyped, socialization-based patterns in cognitive abilities, mathematical competencies, behavior, and motivation are assumed to be so deeply entrenched that the intervention may have limited impact on them. By contrast, when boys do not outperform girls—which may be unexpected given established gender gaps (e.g. Kennedy et al., 2025)—authors tend to rely on external attributions. Such explanations highlight external factors that may have counterbalanced socialization-based differences, including the gender-friendliness of instruments, interventions, or tools, or the mathematical context. The fact that the only study reporting positive effects for girls draws on both internal and external attributions suggests that both internal student characteristics and external intervention conditions contributed to the positive outcomes for girls.

Explanatory patterns that rely on internal attributions highlight the strong influence of socialization processes, as they demonstrate that single teaching units face considerable challenges in counteracting deeply rooted beliefs. Such internalized attributions are generally difficult to change and would typically require long-term educational efforts. Within the scope of a single intervention, however, teachers have more immediate leverage through the design of gender-sensitive instructional approaches—an aspect reflected in a category of external attribution (E2). In line with this, the review shows that in cases where no gender differences were observed, this finding was consistently explained by the use of well-designed, gender-responsive interventions.

Although our findings echo some conclusions reached by Lin and Wong (2024), such as the inconsistency in the direction of the effects reported, our review diverges in scope and orientation and draws on a different literature base, particularly studies with a mathematics focus. We chose the context of mathematics education specifically to examine the integration of CT in a field that is itself characterized by gender disparities. An additional contribution of our study is the classification of explanatory patterns within the framework of Weiner's (1985) Attribution Theory. Still, our work has limitations. The small corpus could limit generalizability, and restricting the review to peer-reviewed English-language publications may introduce language and publication bias. The analysis partly captures authors' explanatory framings rather than empirically tested causal mechanisms and may therefore reflect interpretive tendencies. Substantial heterogeneity across studies (e.g., in duration and CT conceptualization) could limit comparability. Finally, the reliance on binary conceptions of gender and a single theoretical lens leaves intersectional and alternative perspectives unaddressed.

To conclude: The current results emphasize that it is possible to design learning environments for integrating CT into mathematics instruction in a way that eliminates socialization-based gender differences. This implies that internalized gender-related factors can be mitigated through careful planning of instruments, learning environments, mathematical tasks, and deliberate counteraction of teacher bias, thereby supporting equitable learning opportunities. However, creating such gender-friendly environments is not trivial and, as evidenced by the number of studies reporting effects in favor of boys, not straightforward. It therefore requires explicit and careful planning, as well as background knowledge and expertise (e.g., Gildehaus, 2024). However, the number of studies reporting effects in favor of boys also demonstrates that gender-sensitive design is by no means guaranteed. This perspective is particularly relevant for practitioners, as internal factors derive from lifelong socialization processes over which teachers have limited influence. In contrast, teachers can meaningfully shape external factors, including the selection of gender-friendly measuring instruments, interventions, tools, mathematical contexts, and reflect their own attitudes and expectations. As Grover and Pea (2013) emphasize, achieving gender fairness remains a major and ongoing challenge. This review, however, indicates that it can be addressed through gender-responsive instructional design. Consequently, further research should focus specifically on learning environments that

produce no gender effects or those that favor girls. Such targeted analyses can provide more detailed guidance for the development of learning environments that enable equitable opportunities for CT in mathematics education.

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