Engaging Female Students in Computing: A Literature Review

ONYINYE UKENERU-STEVE, University of the District of Columbia

Onyinye Ukeneru-Steve is currently pursuing her PhD at the University of the District of Columbia. She is passionate about gender equity and engagement in computer science education. Her literature review examines the factors affecting female engagement in computing as well as intervention strategies.

Dr. Lily Liang, University of the District of Columbia

Dr. Lily Rui Liang is a full professor and Graduate Program Director at the Department of Computer Science and Information Technology, University of the District of Columbia. Dr. Liang joined the University of the District of Columbia in 2004 after receiving her Ph.D. in Computer Science and Engineering from the University of Nevada, Reno, Nevada. Her research areas include computer science education, cybersecurity, artificial intelligence, and digital image processing. She has mentored dozens of graduate and undergraduate students in research and K-12 outreach activities and is the Director of the Excellence in Computing and Information Technology Education (ExCITE) program. She is a fellow of the Center for the Advancement of STEM Leadership Program (CASL) and the Opportunities for Under-Represented Scholars (OURS) post-graduate institutional leadership certificate program and an alumna of the Frontiers of Engineering Education program (FOEE) of the National Academy of Engineering. She has been serving on the Project Kaleidoscope (PKAL) Capital Area Regional Network steering committee since 2016.

Dr. Briana Lowe Wellman, University of the District of Columbia

Dr. Briana Lowe Wellman is a Professor of Computer Science and Information Technology at the University of the District of Columbia (UDC), where she also serves as Associate Dean of Academics in the School of Engineering and Applied Sciences. She joined UDC in 2012 after earning her Ph.D. in Computer Science from the University of Alabama. Her research interests include multi-robot systems, artificial intelligence, and computing education. Dr. Wellman is deeply committed to broadening participation in computing and developing innovative programs that prepare underrepresented students for success in STEM fields.

Rui Kang

Rui Kang is Professor of Secondary Education (6-12) of Georgia College & State University (GCSU). She teaches graduate courses in numerous areas, including math pedagogy, assessment, educational research, and learner development. She holds two Ph.D. degrees, in Curriculum and Instruction from Texas A&M University (2007) and in Mathematics Education from the University of Georgia (2022). Her scholarship focuses on mathematics teaching and learning, STEM education, and teacher preparation and professional development. Her 20+ publications include articles that appear in journals such as International Journal of Science and Mathematics Education, Journal of Social Studies Research, School Science and Mathematics, and Mathematics Teacher. She served as the Program Chair of the Special Interest Group (SIG) Democratic Citizenship in Education of the American Educational Research Association (AERA) from 2016 to 2018. She has taught high school mathematics and holds a clear renewable teaching certificate in mathematics in the state of Georgia. She currently serves as a Co-Principal Investigator (Co-PI) of a National Science Foundation (NSF) S-STEM grant.

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Abstract

Despite national efforts to promote diversity in STEM, the underrepresentation of girls in computing persists, particularly in urban school districts. The future technology workforce is constrained by gender disparities in computer science education, particularly in K-12 learning environments.

In this paper, we examined the literature in the following areas: 1) the factors affecting female engagement in computing; 2) the pedagogical interventions to engage k-12 female students in computing; and 3) challenges in engaging female students such as workplace and educational barriers; 4) gender equity initiatives such as diversity training, structured mentoring programs, and career advancement paths; and 5) policy interventions and national strategies to improve female engagement. We also reviewed the methodologies in computing education research, including qualitative, quantitative, and mixed-methods approaches.

Our review revealed that the persistent gap in female engagement in computing was due to a combination of structural, pedagogical, social, and cultural factors, such as early exposure and access to technology, curriculum content, pedagogical approaches, teacher attitudes, gender bias, parental and peer influence, media representation, and role models. These findings highlight the systemic obstacles that restrict engagement. It is critical for educators and politicians to address these crucial areas.

Early access and exposure to technology affect female engagement in computing. The poverty and environmental constraints exacerbate gender disparities, especially in underserved minority communities, where there is limited or no access to technology, which continues to restrict opportunities for young women to participate. Teacher attitudes and gender biases further influence girls' participation. These biases could stem from the learning materials or classroom resources selected, thereby unconsciously influencing how educators encourage students. Cultural norms in some communities reinforce gender stereotypes, discouraging girls from participating in computing. Collectively, these findings underscore the importance of developing programs that go beyond access to fostering meaningful, equitable engagement for girls.

We recommend a multidimensional approach to increase girls' engagement in computing: early and equitable access to technology, inclusive curricula, bias-aware teaching, strong family and peer support, visible role models, and strategies to address socioeconomic barriers. Educators and politicians must address these areas and the root causes of gender disparities rather than relying solely on enrollment statistics. Such interventions in computer science education will not only diversify the technology workforce but also enrich computer science by including diverse perspectives and talents.

1. Introduction

Women have played foundational roles in the development of computing, from Ada Lovelace's creation of the first algorithm in 1843 to the women programmers of the Electronic Numerical Integrator and Computer (ENIAC) in 1945. Despite these early contributions, women's representation in computing began to decline significantly after the mid-1980s. At their peak around 1984, women earned approximately *37%* of bachelor's degrees in computer science in the United States [1],[2]. Since then, women's participation has consistently been lower than men's across K-12 education, higher education, and the computing workforce. According to NCWIT (2016), women comprise approximately *26%* of the United States computing workforce [3], highlighting the persistence of gender disparities and the need to further explore the factors influencing girls' engagement in computing education.

This literature review critically analyzes empirical research on girls' engagement in K-12 computing education to identify common patterns, assess the effectiveness of intervention strategies, and reveal methodological and conceptual gaps in current studies. The review synthesizes research on girls' experiences, perceptions, and barriers in computer science education and examines how pedagogical practices, learning environments, and institutional structures affect participation. Attention is given to evidence from qualitative, quantitative, and mixed-methods studies, including research based on interviews, focus groups, classroom observations, and large-scale participation data.

To enhance transparency and methodological rigor, the review relies on peer-reviewed studies identified through systematic searches of major education databases, including Education Resources Information Center (ERIC), Journal Storage (JSTOR), and ProQuest Education. The literature is organized thematically to synthesize findings across methodological approaches and identify recurring patterns that influence girls' engagement in computing. Key themes emerging from literature include structural factors such as access to computing opportunities and curriculum design; social influences such as parental expectations and media representation; and classroom dynamics such as teacher attitudes, peer interactions, and gender bias. Together, these factors contribute to the ongoing participation gap observed across educational levels.

Unlike earlier reviews that mainly focus on postsecondary computing education or broader STEM involvement, this study presents empirical research on female students' participation during the critical K-12 years, when interest, identity, and career goals in computing often begin to develop. By integrating results from qualitative, quantitative, and mixed-methods studies, the review offers a thorough understanding of the factors that influence girls' participation, identity formation, and persistence in computing learning environments, and underscores implications for creating more inclusive and equitable computing pathways. A key distinction this review addresses is whether the participation gap arises primarily from limited course availability in K-12 settings or from girls choosing not to enroll when courses are offered, a distinction that carries important implications for intervention design.

Finally, the review highlights the limitations of current research and emphasizes the need for an equity-focused, context-specific, multidimensional approach to support girls' participation in K–12 computing education.

1.1 Background

Computer science is a key driver of economic growth, yet persistent gender disparities limit girls' participation, beginning in K–12 education. As noted, women remain significantly underrepresented in the computing workforce, and national data show low participation by girls' in Advanced Placement (AP) Computer Science courses [3],[4]. These gaps are more severe in urban districts for example, enrollment data from the District of Columbia Public Schools (DCPS) indicate that girls' enrollment in computing courses fell below 20% as of 2023 [5].

Reviews link underrepresentation to gender stereotypes in Science, Technology, Engineering, and Mathematics (STEM), limited access to culturally relevant curricula, a lack of female role models, and structural barriers, including resource inequities and a lack of teacher preparedness. Empirical studies and systematic reviews link female underrepresentation in computing to several structural, economic, and social factors. Evidence suggests that early exposure, mentorship, and project-based learning can improve girls' engagement.

Research identifies several interconnected factors shaping girls' participation in computing. These include sociocultural influences such as gender stereotypes and limited role models, structural barriers including unequal access to computing resources and insufficient teacher preparation, and curricular challenges related to the lack of culturally responsive learning environments. In response, a range of interventions, including inclusive curricula, mentorship programs, and policy mandates, have been implemented to broaden participation in computing.

While many initiatives report positive outcomes, findings are inconsistent, and questions remain about their scalability and long-term impact [6]. Despite the growing number of studies examining gender disparities in computing, existing research often focuses on isolated interventions or specific educational contexts. A comprehensive synthesis of evidence examining girls' engagement across K-12 computing education remains limited. These limitations highlight the need for systematic synthesis of existing research to better understand the factors affecting girls' engagement in K-12 computing education, to inform the development of more effective and inclusive educational interventions, and to assess the strength of the existing evidence and guide future research and practice.

1.2 How literature was selected

A comprehensive search was conducted across the Education Resources Information Center (ERIC), Journal Storage (JSTOR), and Google Scholar to identify peer-reviewed studies, conference papers, and books. Search terms included : ("female*" OR " girl*" OR "women') AND ("comput*" OR "computer science") AND ("K-12" OR "elementary" OR "secondary" OR "high school "). Additional sources were drawn from Code.org, NCWIT, and the College Board. A total of 156 articles were identified through initial keyword searches. Titles and abstracts were screened for relevance, methodological rigor, and focus on gender and K–12 computing. Of these 25 studies, 10 were qualitative, 12 were quantitative, and 3 were mixed-methods and met the inclusion criteria and were included in the final review.

Studies were included if they examined girls' engagement in the K-12 computing context, used empirical methods, and provided sufficient methodological detail to assess rigor. Studies focusing solely on higher education or workforce outcomes without explicit connections to K-12 pathways were excluded, as were non-empirical publications.

Screening followed a multi-stage Joanna Briggs Institute (JBI) methodology for structured systematic reviews and was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This process included title and abstract screening, followed by full-text screening. Studies lacking methodological transparency were excluded to ensure analytic rigor.

Qualitative studies were evaluated using credibility and transferability criteria, quantitative studies were assessed for internal and external validity, and mixed-method studies were evaluated for integration quality and strand-specific rigor. [6], [7].

Data were thematically synthesized using an inductive approach to identify recurring patterns across studies, allowing for the integration of statistical trends with contextual insights into girls' lived experiences in computing education. This method enables a comprehensive synthesis of evidence across different methodological traditions, building on previous reviews that have examined quantitative and qualitative findings separately.

2. Prevalent exploratory and descriptive research reviews

Research on female students' engagement in computing literature is mostly exploratory and descriptive, focusing on identifying barriers, participation patterns, and attitudes rather than testing large-scale causal models. Prior studies have commonly used surveys, interviews, classroom observations, and case studies to document disparities and student experiences across K–12 and postsecondary settings [8],[9]. While these approaches are valuable for mapping gender inequities, they offer limited insights into causal mechanisms and long-term outcomes. Scholars have thus highlighted the need for more comprehensive, integrative, and longitudinal research designs [10],[11]. This review addresses this limitation by synthesizing findings from qualitative, quantitative, and mixed-methods studies to provide a more comprehensive understanding of the factors influencing female engagement in K-12 computing education. Accordingly, the following subsections examine how quantitative approaches highlight lived experiences and identity formation, as well as mixed-methods studies that combine statistical evidence with contextual insights within broader structural and developmental frameworks [14].[15].

2.1 Qualitative approaches centering lived experiences and identity

Qualitative methodologies, including interviews, ethnography, and class observations, have been widely used to examine the social, cultural, and institutional factors influencing female participation in computing [8] [12]. These approaches provide critical insights into how classroom environments, gender stereotypes, and identity dominate or under-resourced educational settings. Qualitative research is especially valuable for capturing marginalized voices and uncovering changes in confidence, motivation, and identity that are often not visible through quantitative measures. It has computing, maker-centered learning, and a constructionist environment that supports inclusive participation [13].

Qualitative studies consistently demonstrate that female participation in computing is shaped by the interaction of classroom culture, identity formation, and structural inequalities. For example, Margolis and Fisher's [14] conducted a seminal ethnographic study demonstrating how classroom cultures, peer dynamics, and implicit gender norms marginalize girls in computing environments that appeared neutral on the surface. Similarly, Goode [10] used interviews and classroom observations in urban high schools to show how structural inequalities, such as limited course availability and uneven teacher preparation, intersect with gender and race to restrict access to computing education.

Several studies have further explored these dynamics through semi-structured interviews. For example, researchers examining the experiences of women studying computing across multiple universities found that cultural stereotypes and male-dominated learning environments shaped their perceptions of belonging, confidence, and persistence in computing programs [15]. These perceptions evolved positively when students encountered supportive instructional practices and inclusive classroom climates [15]. Similarly, research on role models highlighted the significance of visible and relatable representations, with participants interpreting these as affirmations of their own potential to succeed in computing [16]. These qualitative accounts illuminate the nuanced social and contextual factors that influence girls' engagement beyond what quantitative measures alone can capture.

This review builds on these insights by integrating qualitative findings with quantitative and mixed-methods evidence to provide a more comprehensive understanding of the factors influencing female engagement in K-12 computing education.

2.2 Quantitative Evidence of Participation Gaps and Structural Inequities

Quantitative research provides reliable evidence of ongoing gender gaps in computing education and careers. Large-scale national datasets and surveys consistently show underrepresentation across K–12, postsecondary education, and the workforce. Statistical analyses link lower confidence, a diminished sense of belonging, and unequal access to courses to dropping out of computing pathways. Recently, there has been an increase in experimental studies, including randomized controlled trials, that show improved methodological rigor, though their effect sizes tend to be modest. These reviews play a crucial role in shaping policies and large-scale educational programs.

Several longitudinal and cross-sectional studies using survey and academic record data from over 7,000 students demonstrate that gender gaps emerge early and widen over time [11]. These studies found that female students were significantly less likely to persist in computing pathways [11], largely due to lower self-efficacy and a diminished sense of belonging rather than differences in academic preparation. Similarly, national survey data analyzed by Google and Gallup [5] revealed that girls were less likely than boys to be exposed to computing courses in K-12 settings, particularly in schools serving low-income and racially diverse populations.

2.3 Emergence of experimental and intervention-based reviews

A smaller but emerging body of research reviews employs experimental and quasi-experimental methods to assess interventions aimed at increasing girls' participation in computing. Randomized controlled trials of approaches like storytelling, pair programming, gamification, and collaborative learning demonstrate immediate increases in engagement [11]. However, systematic reviews highlight that many of these interventions lack long-term follow-up, making it difficult to determine if effects are sustained [17]. This trend indicates a methodological shift towards evidence-based testing and also exposes existing gaps in long-term impact and scalability [18].

2.4 Integration through mixed-methods research

Mixed-Methods Research (MMR) serves as a bridge, combining quantitative breadth with qualitative depth to explain not only whether disparities exist but also why they persist. It uses surveys, assessments, interviews, and observations to support triangulation and enhance validity [19]. Systematic reviews consistently indicate that mixed-method approaches are especially effective for equity-focused studies, as they place statistical trends within real-world contexts and institutional experiences [20]. Common methods include sequential and convergent designs, joint displays, and purposive sampling to connect participation data to themes such as identity, access, and pedagogy.

Researchers frequently employed mixed-methods designs to strengthen the validity of self-reported data through qualitative explanation while simultaneously examining how girls' lived experiences corresponded with broader statistical patterns. Throughout the literature, mixed methods were used not only to corroborate findings from multiple data sources but also to uncover the underlying mechanisms that explain the observed quantitative effects.

For example, Goode [10] combined survey data with in-depth interviews to examine both structural conditions and individual experiences influencing female participation in high school computing courses. This integration revealed that access to resources, teacher advocacy, and supportive instructional practices were critical in shaping girls' engagement.

2.5 Methodological Alignment with Equity and Transformative Paradigms

Methodologically, many reviews were grounded in pragmatic and transformative paradigms, emphasizing equity, social justice, and the inclusion of marginalized voices [21]. Researchers explicitly align their methodological choices with the goals of reducing gender disparities and improving access to computing education. This alignment is evident in the widespread use of culturally responsive methods, participatory approaches, and mixed-methods designs that foreground credibility, transferability, and contextual relevance over narrow generalizability [2].

2.6 Historical and Institutional Context Shaping Research Approaches

Historical analyses place current methods within the larger context of changes in computing professionalization and gendered labor dynamics. As women's participation waned from its mid-20th-century high point, research shifted toward identifying systemic exclusion and guiding policy solutions [2]. The formation of groups like the National Center for Women & Information Technology exemplifies this transition, with scholarship increasingly embracing practical, intervention-focused, and equity-centered approaches to tackle persistent disparities.

3. Factors Influencing Female Students' Engagement in Computing

Women remain substantially underrepresented in computing education and the workforce across studies at the national, regional, and local levels. Historical data reveal that women's participation peaked in the mid-1980s, comprising *37%–38%* of computer science degrees, then declined to approximately *18%* by 2008, with a partial recovery to about *22%* in recent years [2],[22]. Current datasets like the Taulbee Survey, Code.org, and the College Board reveal that gender disparities appear early in K–12 education, persist through postsecondary stages, and continue into the workforce [23], [4] . Local analyses, such as DCPS enrollment data, also highlight notable gender gaps, especially in resource-limited urban districts [5]. Overall, these patterns indicate that gender inequities in computing are deeply rooted, longstanding, and resistant to broad, structural changes requiring systemic reforms rather than incremental adjustments.

3.1 Structural and institutional barriers to participation

Structural inequalities, such as unequal access to coursework, technological infrastructure, and trained educators, seriously restrict girls' participation in computing [10],[5]. These issues are exacerbated by geographic factors, with urban schools often facing greater resource shortages than suburban schools. Reviews consistently reveal that girls of color in low-income urban districts experience compounded challenges related to race, class, and gender [14], [24]. Access to early computing opportunities is inconsistent, and policy initiatives frequently fail to ensure uniform implementation across schools and districts [10], [23]. These results highlight the need for systemic reforms focusing on access, funding, and institutional capacity, rather than relying solely on individual interventions.

3.2 Sociocultural influences, stereotypes, and identity formation

Sociocultural norms and gender stereotypes heavily influence girls' views of computing as a male-oriented field [10],[5]. Media, cultural stories, and classroom practices reinforce the idea that computing is tough, male-dominated, and not aligned with girls' identities. Teacher expectations and unconscious biases also affect participation by shaping how they encourage, evaluate, and interact with students [14], [24]. Research consistently shows that exposure to female role models and inclusive representations boosts confidence, fosters a sense of belonging, and encourages persistence. These findings highlight the need for identity-safe learning environments that challenge stereotypes and promote girls' presence in computing.

3.3 Psychological factors: self-efficacy, confidence, and belonging

Girls' participation in computing strongly depends on self-efficacy, confidence, and a sense of belonging [12], [25] . Even when performance levels are similar, girls often report less confidence and greater anxiety about computing tasks. Early exposure, supportive environments, and mentorship play key roles in shaping attitudes and encouraging persistence. Reviews repeatedly highlight that improvements in confidence beyond just skills are vital for sustained involvement [9], [11] . These findings indicate that successful interventions should target psychological factors of engagement as well as curriculum content [18], [5].

3.4 Family, peer, and community influences

Family expectations, parental education, and peer norms significantly influence girls' paths in computing. Parents with STEM backgrounds are more inclined to support their daughters' participation and question traditional gender roles, while a lack of familiarity with computing can strengthen stereotypes. School peer cultures also affect course choices and sustained engagement, either encouraging or hindering girls' involvement. These social forces act alongside formal educational systems, collectively shaping trends in computing participation.

3.5 Curriculum design and pedagogical practices

Inclusive, culturally responsive, and project-based pedagogies are consistently linked to higher female participation in computing. Inquiry-based curricula that connect computing to real-world problems and students' lived experiences foster engagement and persistence, particularly among girls and students of color. Collaborative learning, creative computing, and interdisciplinary approaches challenge narrow definitions of computing competence. Across studies, pedagogy emerges as a powerful lever for equity when intentionally designed to support diverse learners.

3.6 Intervention programs and equity-focused pathways

Targeted interventions, including nonprofit, school-based, and out-of-school programs, have demonstrated encouraging results in increasing girls' engagement in computing. Programs like Girls Who Code, TechNovation, and Compu Girls emphasize mentorship, culturally relevant curricula, and purpose-driven projects. Evidence shows enhancements in confidence, perseverance, and identity development, particularly among girls from marginalized backgrounds. Nonetheless, the literature also points to variability in program implementation and sustainability, highlighting the need for better integration into official school systems.

3.7 Workforce continuities and attrition

Workplace research shows that barriers experienced in K–12 and postsecondary education persist into computing careers. Women face hiring bias, pay inequities, microaggressions, and work–life balance challenges, which contribute to higher attrition rates. These continuities suggest that educational inequities are part of a broader lifecycle of exclusion, reinforcing the importance of early, sustained interventions that address both preparation and persistence.

4. Summary of key findings

Across the systematically reviewed literature, evidence consistently demonstrates that female underrepresentation in K-12 computing education is not the result of ability differences but rather the outcome of a range of structural, pedagogical, social, cultural, and economic factors [9], [12], [16]. Gender disparities emerge early in the educational pipeline and are reinforced over time through inequitable access to computing opportunities, curricular structures, teacher expectations, limited role models, and persistent cultural stereotypes.

Quantitative reviews provide robust evidence of unequal participation patterns, showing lower enrollment and persistence rates for girls, particularly girls of color, in computing coursework and advanced pathways [22], [5]. Qualitative studies complement these findings by illustrating that classroom climates, identity formation, and perceptions of belonging shape engagement and decisions to persist in computing [14].

Mixed-method reviews offer particularly compelling insights by showing how context and implementation conditions mediate intervention outcomes. Evidence from evaluations of inclusive curricula and culturally responsive pedagogies indicates that improvements in participation are closely linked to instructional practices that emphasize relevance, collaboration, and identity affirmation [10], [20] . However, these gains remain uneven across schools and districts, particularly in under-resourced urban contexts.

5. Limitations in the literature on female engagement in computing.

Research on female involvement in computing remains limited by a focus on national data, a scarcity of urban and local studies, a lack of intersectional analysis, few long-term investigations, and minimal use of mixed-methods research. This results in only a partial understanding of girls' experiences and their engagement over time. Most studies do not follow girls' participation in computing over extended periods; instead, they examine short-term interventions without analyzing long-term outcomes. Additionally, research often misses intersectionality, addressing gender in isolation while overlooking factors such as race, class, disability, and language influences [19].

5.1 Need for mixed methods approaches.

Research on female engagement in computing often overlooks mixed methods and early childhood, despite evidence that attitudes develop early [12]. To better understand environmental, psychological, and social influences, context-specific mixed-methods studies are essential. These will support the creation of sustainable and equitable pathways for girls in K–12 computing education.

6. Conclusions

In conclusion, this review shows that gender disparities in K-12 computing education are persistent, multifaceted, and deeply embedded within broader educational and social systems. While promising intervention strategies exist, their effectiveness depends on coherent implementation, contextual responsiveness, and sustained institutional support. By synthesizing evidence across methodologies and contexts, this review provides a comprehensive understanding of the factors shaping female engagement in computing and highlights the need for equity-centered, mixed-methods research to inform future practice and policy.

Research on the gender gap in computing education is essential to developing effective strategies to attract and retain women. This literature review examines historical, social, educational, and institutional factors that contribute to the underrepresentation of women in computing. It finds that girls encounter interconnected social, psychological, and structural barriers, including gender stereotypes, limited access to resources, a lack of female role models, and biased curricula and teaching methods [9], [12],[10] . Quantitative data confirm ongoing underrepresentation in K–12 computing and highlight the benefits of mentorship and inclusive programs [22],[10], [15]. While interventions show promise, gaps persist, especially in local and urban settings and in the intersecting influences of race, access, teacher attitudes, and culture.

7. Recommendations for future research

This review identifies several priorities for future research. First, there is a critical need for longitudinal studies of girls' engagement in computing across multiple educational transitions, from elementary school through postsecondary pathways [11], [16] . These reviews are essential for understanding persistence rather than short-term participation.

Second, future research must more fully integrate intersectional analyses examining how gender interacts with race, socioeconomic status, and school context to shape computing experiences [20], [15]. Reviews that fail to disaggregate data risk obscuring the disparities faced by girls from marginalized communities.

Third, the literature would benefit from greater use of equity-centered mixed-method designs that combine rigorous quantitative measurement with in-depth qualitative inquiry [19], [6]. Such approaches are particularly well-suited to examining implementation processes and explaining variation in outcomes across contexts.

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