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Exploring the Gender Disparities in Computing Education Motivation

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Abstract

This article investigates gender disparities in Computer Science (CS) and Computational Thinking (CT). Existing literature reveals the gender gaps in CS and CT, spanning from the classrooms to the workforce. The literature that identifies the gender gaps in CS and CT and the lack of consensus in the current studies undertaken in relation to why women are less engaged in CS and CT than their male counterparts. The article explores concepts of motivation and engagement and advocates for early exposure to CS and CT. Strategies such as early exposure and offering role models and mentorship programs are proposed as effective ways to attract and retain female learners. Challenges in defining Computing Education terminology and assessing the long-term impact of interventions persist. This article emphasises the need for further research to understand factors influencing girls' motivation and engagement in Computing Education. In conclusion, this article suggests the importance of leveraging practical pedagogical approaches to create a more inclusive learning environment.

Keywords

Gender Disparities, Computer Science Education, Computational Thinking, Motivation, Inclusivity

Introduction

Over the last few decades, we have seen significant shifts in Digital Technology (DT) and its role in our schools, workplaces, and personal lives. With the development of the digital age, DT has had a steadfast place in worldwide curriculums for some time, predominantly as Computer Science Education at high-school and beyond. At present, there are well-documented lower rates of women than men in the Computer Science (CS) sector (e.g., Cebr, 2020; Cheryan et al., 2017; Digital Skills

Forum, 2021; National Science Foundation, 2017; U.S. Bureau of Labor Statistics, 2023; Wang et al., 2021). This is significant, as DT plays an increasingly pivotal role in everything we do. In CS, gender bias occurs, amplified by the lack of diverse and proportionate representation of genders (Breidenbach et al., 2021; Kuppler, 2022; UNESCO, 2018). Algorithms are increasingly used to make significant decisions in aspects such as who can obtain insurance, mortgage allocation and facial recognition, to name a few. When a predominant race or gender creates these algorithms, a coded bias can occur. Given this, there has been a push to prompt CS at the younger levels of schooling. Over the last decade, primary curriculums internationally (e.g., in England, New Zealand and Australia) have been expanded to ensure students are not only passive users of devices but instead are informed, creative developers and users of DT who are gaining the skillsets needed for the 21st Century (Cebr, 2020; Ministry of Education, 2007; Papadopolous, 2017). These new curricula introduced aspects such as Computational Thinking (CT) to students from age five, exploring elements of Computing Education that take place both on and off devices.

Methodology

This narrative literature review aimed to gain a broad, qualitative, critical analysis of empirically reported conceptions about gender-related differences in CT and CS education, with a particular emphasis on girls' motivation and engagement in these fields. To maintain a thorough perspective, the review examined peer-reviewed papers, conference proceedings and institutional reports. This literature review establishes the rationale for further research into girls' motivation in primary school Computing Education, specifically in CS and CT. To achieve this, the article critically examined existing research on females' participation in CS, spanning both professional and tertiary educational settings. It then summarised studies exploring girls' motivation in CT and CS at early childhood, primary and high school; and outlined findings and their actionable suggestions for enhancing practices. Recognising the significance of bridging the gender gap, the article sets the scene and advocates for the critical need for further research in this domain.

The review is guided by the following questions:

1. What are the key gender-related differences in participation, motivation, and engagement in CT and CS education?
2. What insights does the literature offer about addressing gender gaps in CT and CS education?

The review prioritised articles post-2015, with the exception of relevant research aligning with key definitions. Key search terms included "gender"/"girls"/"female", "motivation", and "Computational Thinking", with interchangeable terms such as "engagement", and variations such as "Computer Science", "CT", "informatiks", "digital technology", "coding", "programming". To improve readability throughout this paper, CT and CS (when combined) have been substituted for Computing Education, although this term is typically associated with and includes a far broader range of skills such as Digital Literacy and Digital Fluency. The articles reviewed were all written in English, and no specific criteria were applied regarding the country of origin. However, the majority of the articles originated from countries such as the United States, Canada, Hong Kong and European nations.

Framework

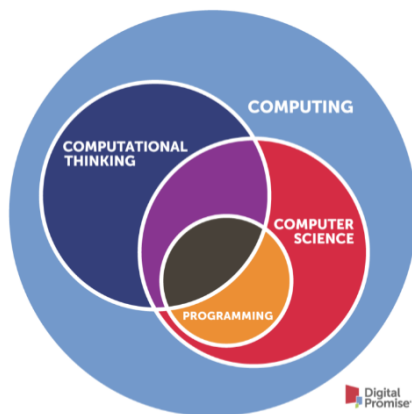
Computational Thinking and Computer Science

CT is often mistaken as a computer-based process due to its name. However, CT revolves around human problem-solving abilities (Curzon et al., 2014). Wing (2006) emphasises CT's importance as akin to reading and numeracy in daily life. CT serves as the foundation of CS but primarily involves mental problem-solving before and during device usage (Wing, 2018). Astrachan (2009) defines CT as problem decomposition and explicit problem modelling.

CS encompasses algorithm study, network design, and artificial intelligence, while computing refers broadly to computers (Encyclopædia Britannica, n.d.). Terms such as CS, coding, CT and computing are often used interchangeably; however, they hold different meanings. Despite their interchangeability and although there are overlapping elements, coding, CS and CT differ, as shown in Figure 1. While coding is a part of programming, it has been generalised in educational and other contexts, and apps like *code.org* fuel misconceptions. Although developing skills in one can support the other, semantic changes and misuse of the term "coding" can lead to misconceptions (Akiba, 2022; Sun et al., 2022). Figure 1 illustrates the relationship between CS, CT, computing, and programming, emphasising their interconnectedness and distinctions (Digital Promise, 2022).

Figure 1.

The Relationship Between Computer Science, Computational Thinking, Programming and Computing



Note: Figure from Digital Promise, 2020, para. 3

Despite the growing importance of CS and CT in education, gender disparities in these fields remain a significant concern. Research consistently highlights the underrepresentation of girls in CS and CT, underscoring the need to understand these disparities. Addressing this issue is critical for developing inclusive educational practices that promote equal participation and foster engagement among all learners.

Gender Disparities in Computing

Diversity is the unique differences between people, including gender, race, sexual orientation, religion, and ethnicity (Tiwari, 2022). A workforce that mirrors the diversity of its community is seen

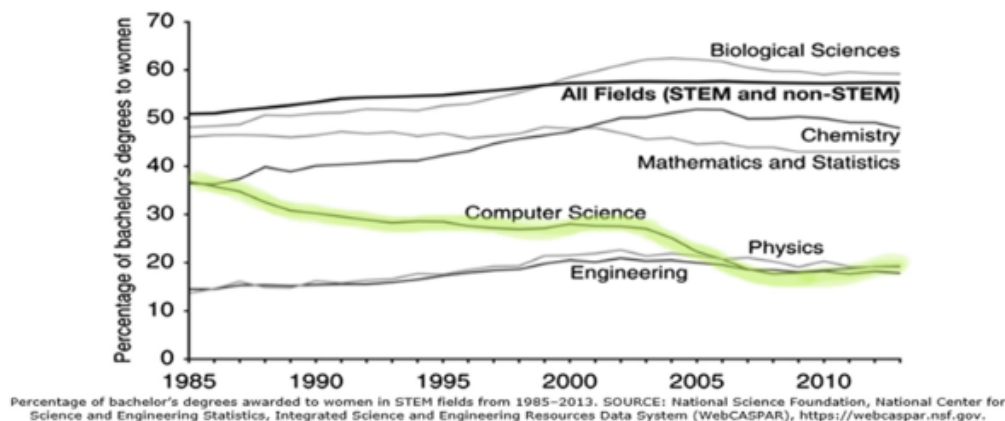
to have benefits. Diversity in CS breeds innovation and creativity, yields high returns for organisations and contributes to new knowledge (Institute of Electrical and Electronics Engineers (IEEE), 2013; Hofstra et al., 2020; Page, 2019; Tiwari, 2022). An important aspect of diversity in Computing Education is gender diversity. Gender is usually understood as the social aspects of one's identity, whereas sex refers to the biological and physical characteristics a person is born with (Erickson-Schroth & Davis, 2020).

Digital technologies are an increasingly large part of every facet of life. Computer-related jobs are growing, and DT is shaping our lives and influencing our thoughts and actions. Therefore, the people who create DT must represent the diverse demographic they innovate for (Bjørn et al., 2023). Current research identifies a gender imbalance of males to females who participate in CS tertiary education, literature creation and occupations (e.g., Cebr, 2020; Cheryan et al., 2017; Digital Skills Forum, 2021; National Science Foundation [NSF], 2017; U.S. Bureau of Labor Statistics, 2023; Wang et al., 2021). In STEM (Science, Technology, Engineering and Mathematics) related studies and occupations, gender disparities exist across the sector.

Tertiary CS education has the least female involvement compared to other STEM subjects. Currently, in some STEM domains, such as biology, mathematics and environmental engineering, gender gaps appear to be diminishing. However, in CS, women remain notably underrepresented, constituting just 22.6% of the conferred Computer and Information Sciences bachelor's degrees in the USA in 2022 (National Centre for Education Statistics, 2023). Additionally, the USA's NSF (2017) reports that proportionally, the number of women achieving CS bachelor's degrees is less than a generation ago, as shown in Figure 3.

Figure 3.

Number of Women Awarded Bachelor's Degrees in CS (Shown in Green)

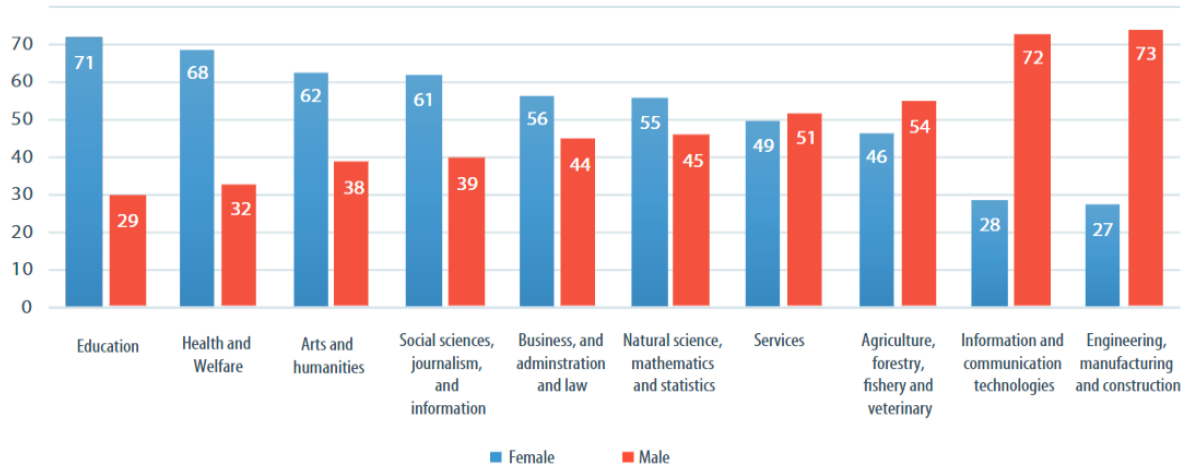


Note: NSF, 2017, para 4.

Additionally, data collected by UNESCO (2017, p. 45) supports the National Science Foundation's (2017) findings globally. Only 28% of those enrolled in higher education ICT fields globally were females (although this includes ICT administrators), as shown in Figure 4.

Figure 4.

Share of Female and Male Students Enrolled in Higher Education, by Field of Study, Global Average.



Note: UNESCO, 2017, p. 45.

A UK report by Cebr (2020), identified that many universities are working to address the underrepresentation of women in STEM fields with little success. Other authors suggest that women are less motivated to be involved in STEM professions, that sociocultural influences, gender-based prejudices and biases, field-specific competence perceptions, lifestyle values, preferences for work-family balance, and inclinations or professional ambitions all have an impact (Alam, 2022; Ortiz-Martínez et al., 2023).

The presence of women is notably lacking in tertiary fields of CS and in the literature. A comprehensive analysis of 11.8 million articles found that, while the number of female authors in CS literature is gradually increasing, it is estimated that gender equality in authorship (based on current trends) will not be achieved until at least the year 2120 (Wang et al., 2021). Furthermore, compared to other industries, the proportion of female authors writing CS articles is among the lowest (Wang et al., 2021).

The same pattern as CS tertiary education and literature appears in CS careers. According to a Digital Skills Report from NZ (Digital Skills Forum, 2021), there is a significant gender imbalance in digital roles, with women accounting for only 27% of NZ's digital workforce. Curiously, despite the number of women in digital positions declining, the total number of women in the workforce has risen over the same period. Another American report (U.S. Bureau of Labor Statistics, 2020) identified that women accounted for only 22% of computer-related occupations of (excluding administrators).

These figures are concerning given women's rich history with computing and coding. In 1833, Ada Lovelace developed what is now recognised as the first "computer program" and as computers became a reality, women were pioneers in writing the software and providing the calculations for the first programmable computer, called the Eniac (Thompson, 2019). Women such as Betty Holberton are credited for developing programming that increased accessibility and practical applications of computers, whilst Margaret Hamilton led the design of software for the lunar mission in the 1950s and '60s, a time where a large proportion of these types of roles were completed by women (Gürer, 2002). However, these female programmers were seldom acknowledged, as the hardware developed

(by males) was seen as the most important contributions. Several decades later and women's participation in computing looks quite different (Gürer, 2002; Thompson, 2019).

The CS gender imbalance, identified in the literature on higher learning and the workforce, is preceded by a lack of Computing Education diversity in schools, particularly in senior years. The lack of diversity in school students' motivation to participate in Computing Education subjects has been researched to try and ascertain when and why women decide that CS is not a career path for them (Yamazaki & Nishida, 2025).

Computational Thinking and Computer Science in Schools

Several reports from Europe and America have accentuated the evolving importance of students being extended to gain a deeper understanding of computers, that there is a need for an overhaul in the education system and that DT plays a role in this (Gander et al., 2013; Koh, 2015; Prensky, 2001; Reigeluth & Joseph, 2002; Su, 2009; Tapscott, 2009; Voogt et al., 2015).

Within digital curricula in schools, CT and CS are often identified as areas of learning (Bell et al., 2014; Webb, 2017), with both subjects evolving since their initial conceptions. Gradually separating from Engineering, CS became a definitive USA tertiary subject in the 1940s (Tedre et al., 2018). Early CS courses aimed at creating new devices. However, as manufacturers mass-produced computers and introduced them to educational institutions, the focus shifted towards the growing need for computer specialists in the labour force. Consequently, schools introduced computer science into US high schools in the 1960s (Tedre et al., 2018).

Over the last 15 years, CT has been introduced to primary classrooms (ages 5 to 13) worldwide. Prior to this, C and CT were predominantly taught in secondary schools or higher-level education and were mainly thought of as CS. In 2003, the United States introduced new primary school Computing Education curricula (Stephenson et al., 2012); in 2014, the United Kingdom followed (Cebr, 2020); in 2015, Australia implemented similar changes (Papadopolous, 2017); and in 2017, New Zealand introduced its own curriculum (Ministry of Education, 2017). These curricula go beyond using devices as tools and digital literacy and instead aim to develop students' understanding of being critical creators of digital devices. Introducing these curricula at lower levels of schooling aims to develop students who are capable of being digitally critical and creative in a world dominated by computers (Caeli & Yadav, 2020). Another motivation for these curricula is the demand for a workforce who can work in digitally-driven industries, such as CS. However, diversity in the CS workforce remains a challenge despite earlier integration into schools.

Developing CT in primary education has been identified as an important way to address gender gaps early (El-Hamamsy et al., 2023; Sullivan, 2021). According to Master et al. (2017), providing middle school students with opportunities to participate in computer-related activities can decrease gender disparities and increase girls' motivation. Given the introduction of CT curricula in primary education and the lack of female representation in tertiary and workforce CS; CT curricula enable an enhanced opportunity to engage females in these fields early (Sullivan, 2021). Mills et al. (2021), suggest that girls are part of a marginalised group who do not get sufficient access to resources and learning opportunities to develop their CT skills. Additionally, it is thought that earlier exposure to CT might remove social and structural barriers (El-Hamamsy et al., 2023).

Results: Descriptive Findings from the Literature

Motivation in Computing Education Classrooms

Motivation can be intrinsic and extrinsic and plays an important role in students' engagement and learning capabilities. The term "motivation" describes the elements that keep students engaged in the classroom, such as their emotions and emotion-related reactions, as well as their cognitions (such as self-perceptions and attitudes about belonging) (Master, 2021). Over time, understanding the motivation to learn has been considered an essential element in education. The volition to learn is also a fundamental aspect educators want to ignite in their students. Models and theories of motivation are widespread. A study by Hattie et al. (2020) compared five motivation articles and identified major dimensions common to all. These included "person factors comprising self (expectations, self-efficacy), social (modelling, comparisons), and cognitive aspects (self-regulation); task values; goals; and perceived costs and benefits" (p. 1). However, Hattie et al. (2020) note that the five articles fail to define motivation categorically. Several theories that relate to motivation in education have been established. Urhahne and Wijnia (2023) propose "the most cited theories of academic motivation include expectancy-value theory, social cognitive theory, self-determination theory, interest theory, achievement goal theory, and attribution theory" (p. 1). The primary constraint associated with these theories lies in the diversity of terminology and ideas individuals use, making it challenging to establish clear boundaries. However, ability and self-concepts are key factors determining whether children engage in a topic (Eccles & Wigfield, 2020; Master & Meltzoff, 2020). Hattie et al. (2020) suggest that motivation in the school environment can be complex due to the need to comply with school requirements.

Learning Motivation in Computing Education: Gender Gaps

Girls are often considered equally motivated as boys to participate in "on-device" games and activities. However, research reveals a conflict with this idea when considering gender differences in engagement and motivation within Computing Education (Fagerlund et al., 2022; Witherspoon et al., 2016). Data from several Computing Education studies have identified that males were more motivated than females, particularly in contributing factors such as self-efficacy and interest (e.g., Kong et al., 2018; Kori & Luik, 2020). Additionally, in Kori and Luik's (2020) study, differences emerged in social influence and perceived abilities, whilst Sun et al. (2022), identified that girls' attitudes towards programming were more negative than their male counterparts. Boys exhibit greater confidence and self-efficacy in STEM fields than girls (Atmatzidou & Demetriadis, 2016; Johnson, 2012). Another study also found that first-grade girls with greater stereotypes of CS being a male-dominated field held less motivation and self-efficacy in CS (Master et al., 2017).

Numerous studies have argued that Computing Education motivation declines the older students become (Román-González et al., 2017; Witherspoon et al., 2016). However, Master et al. (2017), identify that exposure to computer programming assists girls' motivation to engage with Computing Education, a concept endorsed by other researchers (Gursch, 2022; Luo et al., 2020). This view is supported by Fagerlund et al. (2022), who argue that the more time teachers spent on CT instruction, the higher students' programming motivation becomes. Lishinski et al. (2016), build on students' exposure to programming, identifying that the right exposure can create a "self-efficacy feedback loop" where self-efficacy and performance are inversely related and highly malleable.

In contrast, Master et al. (2023), found no difference between male and female students' CT motivation in grades 1-3, and noted that students tend to endorse stereotypes about CS that favour

their own gender. However, these findings may support the notion that motivation decreases in the later years of schooling. Kong et al. (2018), also discovered that students thought programming was less significant in the senior grades than they did in the junior classes, corroborating the idea that CS motivation wanes.

Learning Engagement in Computing Education: Gender Gaps

Motivation is closely related to engagement. Engagement is characterised by attitudes, behaviours, and feelings that align with motivation, inclination, and drive (Collie & Martin, 2019). Both engagement and motivation to learn Computing Education are important aspects in the classroom if learning is to take place. Teachers often seek to engage and motivate students to learn, hoping for a reciprocal relationship between the two elements. Literature on CT proposes that school-aged girls are less likely than boys to engage in CT and other Computing Education activities, particularly as they get older (Fagerlund et al., 2022; Master et al., 2017; Mills et al., 2021). Boys at high school often engage in Computing Education with greater frequency and therefore Master et al. (2023), consider that although males can score higher on Computing Education tests, when females engage at the same rate, there is trivial difference. Additionally, studies have found that there are significant gender differences in how and why students engage in Computing Education activities (Miller & Horneff, 2017) which has implications for the engagement and motivation of students.

Learning Abilities in Computing Education: Gender Gaps

Another aspect that impacts the motivation and engagement of students in CS education is their cognitive abilities. Zhang and Wong (2022) found a direct correlation between students' (9–11-year-olds) cognitive capabilities and their subsequent attitudes toward CT. Some research suggests that there is no significant gender divide in Computing Education abilities when equal participation occurs (Atmatzidou & Demetriadis, 2016; Jiang & Wong 2021; Sun et al., 2022; Sun & Liu, 2023). Although there might be some distinction between the genders in CT and associated area acquisition (Jiang & Wong 2021), this is currently not an area that researchers agree on. Other research found differences in gender CT abilities at the middle to upper primary level, identifying a progressive gender gap (Mouza et al., 2020; Román-González et al., 2017). Although studies identify that it can depend on the Computing Education type, problem and the length of time given to gain the required skillsets (Ardito et al., 2020; Atmatzidou & Demetriadis, 2016; Román-González, 2017). Boys at high school often engage in Computing Education with greater frequency. Therefore, Master et al. (2023) observe that the association between engagement and interest is likely also true for abilities.

Interestingly, a study with 294 over 16-year-olds, found that although males have a higher perception of their abilities in CT than females, females' perceptions tended to be more accurate than males (Vaníček & Šimandl, 2020). Whilst Atmatzidou and Demetriadis (2016) found that both genders frequently acquire the same degree of proficiency in CT, time spent practicing CT is the most crucial component. They point out that girls might require more time to attain the same levels of CT as their male counterparts; however, as men typically spend more time on CT in general, it is unclear from their research how much time males and females spent on CT before the study. A systematic review completed with 12-15-year-olds found that stereotypes were rife in CS and hindered students' interest and career motivation (Spieler et al., 2020). They found evidence that girls felt they needed to be overly intelligent rather than motivated to succeed in CS, which hindered their engagement (Spieler et al., 2020).

Papavlasopoulou et al. (2020), offer a potential explanation for the differing opinions in Computing Education regarding gender and abilities. Their research found that females are no less competent than their male counterparts but tend to approach Computing Education tasks differently. This distinction may influence outcomes when girls are assessed on their coding abilities or motivations, as some studies might inherently favour aspects that align more closely with boys' preferences. For example, Sullivan and Bers (2013) highlighted that competitive environments often give boys an advantage, potentially disadvantaging girls who might excel in collaborative or creative tasks. Additionally, girls may gravitate toward specific types of Computing Education activities that are not always reflected in standardised assessments. To address these disparities, it is essential to design tasks and assessments that align with diverse learning styles and approaches, ensuring an inclusive environment that effectively engages and supports girls in Computing Education.

Engaging Girls in Computing Education

Due to the gender gaps that prevail in CS, girls must be encouraged to develop their Computing Education skills from the outset. Kong et al. (2018), suggest that it is important to consider and put emphasis on what motivates girls to engage with Computing Education, as boys are more motivated to be involved regardless. Various studies express the importance of exposure to Computing Education to decrease the prevailing gender gaps (El-Hamamsy et al., 2023; Fagerlund, 2022; Gursch, 2022; Luo et al., 2020; Master et al., 2017). In addition, several articles have identified aspects that support or develop girls' engagement in Computing Education, explored in the following section. These include early exposure, role models, real-life concepts, utilising both unplugged and plugged-in approaches, gaming and connecting to other curriculum areas.

Early exposure is important for gender equity in Computing Education (El-Hamamsy et al., 2023). A research report from the United States considers that if exposure begins in the lower years of schooling and is sustained throughout, this could in turn, triple the women in CS careers by 2025 (Accenture and Girls Who Code, 2016), although there is no literature to suggest if this is on track. The report identifies several aspects in a three-stage approach that support girls to study and work in computing. At junior high (approximately 12-15 years-old): "Deepen girls' hands-on experience; change girls' perceptions of computing and support parents and teachers in understanding the wider role of computing" (pp. 16-17). At High school (approximately 14-18-years-old): "re-design high school computing courses to appeal to girls, create grassroots campaigns to motivate peer group action and attract more women teachers" (pp. 11-13). At college we need to (18+): "inspire young women towards a career in computing (through) role Models, retooled courses and summer immersion programs, (by) giving Computing courses a makeover, offer female students immersion programs and create female mentorship and role model programs" (pp. 14-16).

Several factors were identified that would facilitate engagement of women in CS (The Australian Council for Educational Research, 2023) investigated factors supporting or hindering female students DT participation. The study emphasised the importance of increasing educators' confidence and awareness, and the need to relate digital technologies to real-world, inclusive contexts, making them more relevant and accessible. Addressing the confidence imbalance among students was another key recommendation, alongside 'early exposure' cultivating interest from an early age. The study advocated for challenging the stereotypical portrayal of digital technologies and providing parents with more information and resources to support their children. Additionally, clarifying that gaming and coding represent only one aspect of digital technologies was also seen as essential. Finally, the research underscored the importance of a stronger focus on encouraging young women to pursue DT subjects and degrees (Banks et al., 2023).

El-Hamamsy et al. (2023) also support many of the above concepts, including that girls have more positive perceptions of CS if they have a role model close to them doing CS. Kong et al.'s (2018) study found that linking CS to real-life problems, encouraging girls to participate in CS, and giving them high recognition were crucial in engaging females and raising their sense of self-efficacy and curiosity. Additionally, utilising a mixed plugged and unplugged approach has been found to support the interests and engagement of both males and females (Sun & Liu, 2023).

Other studies have considered the relationship between incorporating CT with other subjects, such as biology (Gursch, 2022; Kori & Luik, 2020; Corinna & Sabitzer, 2023). One study, undertaken with high-school students in Slovakia and Austria found that incorporating CT skills and Biology – a STEM area known to have equal representation of males to females – helped to motivate 26% of the girls to be involved in CT, and 56% found the combination 'interesting' (Corinna & Sabitzer, 2023). However, it is not clear from these results what interest levels would have been if integrating with other science areas, which are considered to be not as popular with females. Integrating art and animation into CS has increased girls' interest and consideration of pursuing a career in CS (Kori & Luik, 2020). Gursch (2022) explored several approaches to engage girls in computer science (CS). When interviewed about three activities offered, 47% of participants expressed interest in more embroidery programming, while only 21% preferred additional game programming and 5% wanted more time with robotics. However, other research suggests different patterns; for example, Accenture and Girls Who Code (2016) found that girls who play digital games from an early age are four times more likely to pursue careers in computing and coding. These contrasting findings highlight that results may depend on the specific elements of Computing Education provided, which introduces ambiguity and limitations to this literature review.

Discussion

The findings from this review highlight critical themes related to gender-related differences in participation, motivation and engagement in CT and CS education. While much of the literature agrees there are gender disparities and differences in Computing Education, there remains debate around the key aspects of how and why these disparities occur and how to address these.

Males tend to engage with Computer Science more frequently than females, which can lead to higher confidence and sustained future participation among males. However, when females are exposed to Computer Education, their self-concepts and confidence in the subject increase, emphasising the critical role teachers play in fostering engagement and providing opportunities in their classrooms. Additionally, the debate around gender differences in abilities within Computing Education remains inconclusive, further complicated by varying levels of engagement and the specific aspects of Computing Education being assessed.

Research highlights several concepts in education that might impact girls' motivation, many of which can be driven by schools and teachers, such as role modelling, greater teacher training, linking to other curriculum areas and real-life concepts, and high recognition for effort. Additionally, early exposure was identified by multiple articles, which again highlights the importance of teachers including Computing Education in their classrooms and the need for the revamp or addition of these curriculums at the primary school level. While strategies to engage girls in Computing Education have been proposed, there is a lack of comprehensive studies and clear guidance on effectively addressing gender gaps in Computing Education. This underscores the need for more targeted research and evidence-based practices to create equitable and inclusive learning environments.

A limitation of this review of literature is the language used to define CT and CS. Data are often represented in terms of the generalised acronym 'STEM' rather than separated into individual fields. This issue can be worsened by inconsistent terminology used in CS, particularly at the primary education level, where different phrases and terminology might be used to express the same or similar concepts. Different terms, such as coding, programming, CT, CS, STEM, Informatiks, ICT, digital fluency are often used interchangeably as discussed above in the 'what is Computational Thinking' section of this review. Although advocating for a generic term might be plausible, it is unlikely to be feasible due to the nuanced differences among the terms. While many overlap, they frequently have distinctive features. One way to enhance clarity in research is by ensuring that all published studies provide clear and consistent definitions of their terminology. This review identified a significant lack of such definitions in many of the articles and studies analysed, which leads to ambiguity and hinders the comparability and applicability of findings. Establishing precise terminology is essential for advancing understanding and fostering meaningful discussions within the field.

Additionally, caution is taken when assuming that a short-term intervention might have significant gains in changing girls' perceptions or long-term goals, as found in a study by Lang et al. (2015). Lang et al. (2015) developed a "digital divas" outreach program to increase girls' interest in computing careers in Australia. Although the program increased girls' confidence in computing, after taking part, it transpired that the girls were still not likely (if not less likely) to pursue a career in computing. Additionally, exposure to Computing Education alone might not be a positive experience (Master et al., 2023). This perhaps highlights the increased need for greater teacher training and understanding of what motivates girls to be involved in computing.

Furthermore, a challenge in the motivation and engagement of students in Computing Education is how it is taught and assessed. Many of the above studies were quantitative, relied on testing or end-data collection results and tended to focus on the upper-year levels of schooling, where the beliefs and attitudes have already been formed (Román-González, 2017; Witherspoon et al., 2016). This underscores the need for studies with a broader scope, encompassing diverse contexts, populations, and methodologies.

Gaps in Literature related to girls' motivation in Computer Education

Further research is needed to understand gender gaps in CT and CS education. Master et al. (2023) and other researchers (Fagerlund et al., 2023; Kaur & Chahal, 2023; Lishinski et al., 2016; Lye et al., 2014; Sharma et al., 2021; Ye et al., 2022) support the notion that further research is needed to understand girls' Computing Education motivation. Master and colleagues are currently undertaking interviews with students to learn more about how stereotypes influence their engagement with CS, although the outcome and publication date of this is unknown (University of Houston, 2021). Passey (2017) identifies that greater emphasis is needed to understand what makes girls likely to engage in Computing Education. He highlights that developing girls-only coding clubs or bringing in role models is insufficient to change ongoing perceptions of Computing Education. In addition, he specifies several questions that might help the future needs of CT, including:

What forms of pedagogy can teachers deploy to best support the development of CT, problem-solving and creativity through programming skills, for the 5-to-16-year age range?

What approaches enable learners of different ages to engage with CS or computing?

In what ways can this interest and engagement be maintained?

How can different groups of learners be supported most effectively in these Respects? (pp. 439-440)

Two additional aspects pose limitations to this review. Firstly, the literature reviewed was all written in English, with the majority of the articles originating from the United States, Canada, Hong Kong and Europe. This geographic concentration may present a skewed perspective that is not fully representative of global views. Secondly, the term "gender" was seldom clearly defined in the articles, which could lead to inconsistent interpretations and limit the clarity and applicability of the findings across different contexts.

Conclusion

This article examines the gender gap in Computing Education. CT and CS have become integral components of educational systems. However, persistent gender disparities prompt the examination of effective strategies to engage and motivate girls in CT and CS. Despite the apparent similarities between CT and CS, the lack of universally agreed-upon definitions poses challenges in research and understanding. The persistent gender gap in tertiary education and professional careers, along with the underrepresentation of women in CS literature, underscores the importance of early engagement, particularly for girls. The article advocates for diverse strategies, such as introducing role models, real-life applications, and a mix of teaching approaches to bridge gender disparities in CT and CS education. Despite acknowledging limitations, such as the absence of consensus on Computing Education definitions and a focus on upper-level education in existing studies, the article highlights the necessity for research to comprehend gender gaps, motivation factors, and greater clarity on the effective pedagogical approaches for encouraging girls' participation in CT and CS.

References

- Accenture and Girls Who Code. (2016). *Cracking the gender code*.
<https://www.accenture.com/content/dam/accenture/final/a-com-migration/pdf/pdf-150/accenture-cracking-the-gender-code-report.pdf>
- Akiba, D. (2022). Computational thinking and coding for young children: A hybrid approach to link unplugged and plugged activities. *Education Sciences*, 12(11), 793.
<https://doi.org/10.3390/educsci12110793>
- Alam A (2022) Psychological, sociocultural, and biological elucidations for gender gap in STEM education: a call for translation of research into evidence-based interventions. In: Proceedings of the 2nd International Conference on Sustainability and Equity (ICSE-2021), KIIT Deemed to be University, Bhubaneswar, Odisha India, 17–18 December 2021.
<https://doi.org/10.2991/ahsseh.k.220105.012>
- Ardito, G., Czerkawski, B., & Scollins, L. (2020). Learning computational thinking together: Effects of gender differences in collaborative middle school robotics program. *TechTrends* 64, 373–387. <https://doi.org/10.1007/s11528-019-00461-8>
- Astrachan, O. (2009). A new way of thinking about computational thinking. *Journal of Computing Sciences in Colleges*, 25(1), 6–6. <https://dl.acm.org/doi/abs/10.5555/1619221.16192223>

- Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, 75, 661–670. <https://doi.org/10.1016/j.robot.2015.10.008>
- Australian Council for Educational Research (ACER). (2023). *Engaging young female students in digital technology programs*. Commonwealth Scientific and Industrial Research Organisation (CSIRO). https://www.csiro.au/-/media/Education-and-Outreach/Impact-Library/Research-reports/Files/ACER_CSIRO-Report_PartOne.pdf
- Banks, C., Osborne, K., & Buckley, S. (2023, Aug 25). *Factors facilitating greater engagement of young women in digital technologies education*. https://www.teachermagazine.com/au_en/articles/factors-facilitating-greater-engagement-of-young-women-in-digital-technologies-education
- Bers, M. U. (2020). *Coding as a playground: Programming and computational thinking in the early childhood classroom*. Routledge. <https://doi.org/10.4324/9781003022602>
- Bjørn, P., Menendez-Blanco, M., & Borsotti, V. (2023). *Diversity in computer science design artefacts for equity and inclusion*. Springer Nature. <https://doi.org/10.1007/978-3-031-13314-5>
- Breidenbach, A., Mahlow, C., & Schreiber, A. (2021). *Implicit gender bias in computer science - A qualitative study*. <https://doi.org/10.48550/arXiv.2107.01624>
- Butler, D., & Leahy, M. (2021). Developing preservice teachers' understanding of Computational Thinking: A constructionist approach. *British Journal of Educational Technology*, 52(3), 1060–1077. <https://doi.org/10.1111/bjet.13090>
- Caeli, E., & Yadav, A. (2020). Unplugged approaches to computational thinking: A historical perspective. *TechTrends*. <https://doi.org/10.1007/s11528-019-00410-5>
- Cebr, (2020). *Technology in UK schools: A report for Lenovo*. <https://www.lenovo.com/origind8/sites/default/files/2020-01/Technology-in-schools-whitepaper.pdf>
- Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, 143(1), 1–35. <https://doi.org/10.1037/bul0000052>
- Collie, R., & Martin, A. (2019, November 22). Motivation and engagement in learning. *Oxford Research Encyclopedia of Education*. <https://oxfordre.com/education/view/10.1093/acrefore/9780190264093.001.0001/acrefore-9780190264093-e-891>.
- Corinna, H., & Sabitzer, B. (2023). Easy coding in biology: Combining block-based programming tasks with biological education to encourage computational thinking in girls easy coding in biology. *16th International Conference on Informatics in Schools, ISSEP 2023, Local Proceedings*. <https://doi.org/10.5281/zenodo.8431893>
- Corradini, I., Lodi, M., & Nardelli, E. (2018). An investigation of Italian primary school teachers' view on coding and programming. *Informatics in Schools. Fundamentals of CS and Software Engineering*, 228–243. https://doi.org/10.1007/978-3-030-02750-6_18
- Curzon, P., McOwan, P. W., Plant, N., & Meagher, L. R. (2014). Introducing teachers to computational thinking using unplugged storytelling. In *Proceedings of the 9th workshop in primary and secondary Computing Education* (pp. 89–92). <https://doi.org/10.1145/2670757.2670767>
- Digital Promise. (2022, November 27th). *What is computational thinking?* Retrieved 5 November, 2025, from <https://digitalpromise.org/initiative/computational-thinking/computational-thinking-for-next-generation-science/what-is-computational-thinking/>

- Digital Skills Forum. (2021). *Digital skills Aotearoa: Digital skills for our digital future*. https://Nztech.Org.Nz/Wp-Content/Uploads/Sites/8/2021/01/Digital-Skills-Aotearoa-Report-2021_online.Pdf.
- Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology*, 61, Article 101859. <https://doi.org/10.1016/j.cedpsych.2020.101859>
- El-Hamamsy, L., Bruno, B., Audrin, C., Chevalier, M., Avry, S., Zufferey, J. D., & Mondada, F. (2023). How are primary school computer science curricular reforms contributing to equity? Impact on student learning, perception of the discipline, and gender gaps. *International Journal of STEM Education*, 10(1), 60–43. <https://doi.org/10.1186/s40594-023-00438-3>
- Encyclopædia Britannica. (n.d.). *Computer science*. Britannica Academic. <https://www.britannica.com/science/computer-science>
- Erickson-Schroth, L., & Davis, B. (2020). *Gender*. Oxford University Press.
- Fagerlund, J., Leino, K., Kiuru N., & Niilo-Rämä, M. (2022). *Finnish teachers' and students' programming motivation and their role in teaching and learning computational thinking*. <https://doi.org/10.3389/educ.2022.948783>
- Gürer, D. (2002). Women in computing history. *ACM SIGCSE Bulletin*, 34(2), 116-120. <https://doi.org/10.1145/543812.543843>
- Gander, W., Petit, A., Berry, G., Demo, B., Vahrenhold, J., McGettrick, A., Boyle, R., Drechsler, M., Mendelson, A., Stephenson, C., Ghezzi, C., & Meyer, B. (2013). Informatics education: Europe cannot afford to miss the boat. *Report of the joint Informatics Europe & ACM Europe Working Group on Informatics Education*. <https://www.informatics-europe.org/images/documents/informatics-education-acm-ie.pdf>
- Gursch, S. (2022). Coding initiative provides different approaches to inspire girls for programming. Proceedings of the 30th International Conference on Computers in Education. *Asia-Pacific Society for Computers in Education. Volume I*, 2022: 655-659.
- Hattie, J., Hodis, F. A., & Kang, S. H. K. (2020). Theories of motivation: Integration and ways forward. *Contemporary Educational Psychology*, 61(May). <https://doi.org/10.1016/j.cedpsych.2020.101865>
- Hofstra, B., Kulkarni, V. V., Munoz-Najar Galvez, S., He, B., Jurafsky, D., & McFarland, D. A. (2020). The diversity–innovation paradox in science. *Proceedings of the National Academy of Sciences*, 117(17), 9284–9291. <https://sts.stanford.edu/publications/diversity-innovation-paradox-science>
- IEEE Computer Society. (March 2, 2013). *Why diversity in computing Matters: Wendy DuBow* [Video]. YouTube. <https://www.youtube.com/watch?v=TgNJJzSiBiY>
- Jiang, S. & Wong, G. K. W. (2017). Assessing primary school students' intrinsic motivation of computational thinking. In *2017 IEEE 6th International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 469–474). <https://doi.org/10.1109/TALE.2017.8252381>
- Johnson, A. (2012). *A short guide to action research* (4th ed.). Allyn and Bacon.
- Kaur, A., & Chahal, K. K. (2023). Exploring personality and learning motivation influences on students' computational thinking skills in introductory programming courses. *Journal of Science Education and Technology*, 32, 778–792. <https://doi.org/10.1007/s10956-023-10052-1>
- Koh, C. (2015). *Motivation, leadership and curriculum design: Engaging the NET generation and 21st century learners*. Springer. <https://doi.org/10.1007/978-981-287-230-2>

- Kong, S.-C., Chiu, M. M., & Lai, M. (2018). A study of primary school students' interest, collaboration attitude, and programming empowerment in computational thinking education. *Computers and Education*, *127*, 178–189.
<https://doi.org/10.1016/j.compedu.2018.08.026>
- Kori, K., & Luik, P. (2020). Upper- and lower-secondary students' motivation to study computer science. In K. Kori, & M. Laanpere (Eds.), *Informatics in Schools. Engaging Learners in Computational Thinking*. ISSEP 2020. Lecture Notes in Computer Science, vol 12518. Springer, Cham. <https://doi.org/10.1007/978-3-030-63212-0>
- Kuppler, M. (2022). Predicting the future impact of computer science researchers: Is there a gender bias? *Scientometrics*, *127*(11), 6695–6732. <https://doi.org/10.1007/s11192-022-04337-2>
- Lang, C., Fisher, J., Craig, A., & Forgasz, H. (2015). Outreach programmes to attract girls into computing: How the best laid plans can sometimes fail. *Computer Science Education*, *25*(3), 257–275. <https://doi.org/10.1080/08993408.2015.1067008>
- Lishinski, A., Lansing, E., Good, J., & Enbody, R. (2016). Learning to program: Gender differences and interactive effects of students' motivation, goals, and self-efficacy on performance, 211–220. ICER '16: Proceedings of the 2016 ACM Conference on International Computing Education Research. <https://doi.org/10.1145/2960310.2960329>
- Luo, F., Antonenko, P. D., & Davis, E. C. (2020). Exploring the evolution of two girls' conceptions and practices in computational thinking in science. *Computers and Education*, *146*, 103759. <https://doi.org/10.1016/j.compedu.2019.103759>
- Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*. Elsevier Ltd. <https://doi.org/10.1016/j.chb.2014.09.012>
- Master, A. (2021). Gender stereotypes influence children's STEM motivation. *Child development perspectives*, *15*(3), 203-210. URL?
- Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A. N. (2017). Programming experience promotes higher STEM motivation among first-grade girls. *Journal of Experimental Child Psychology*, *160*, 92–106. <https://doi.org/10.1016/j.jecp.2017.03.013>
- Master, A., Tang, D., Forsythe, D., Alexander, T. M., Cheryan, S., & Meltzoff, A. N. (2023). Gender equity and motivational readiness for computational thinking in early childhood. *Early Childhood Research Quarterly*, *64*, 242–254. <https://doi.org/10.1016/j.ecresq.2023.03.004>
- Master, A., & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *International Journal of Gender, Science and Technology*, *12*(1), 152–198. <https://genderandset.open.ac.uk/index.php/genderandset/article/view/674>
- Miller, D., & Horneff, M. (2017). Kids, coding and computational tinkering: A practical guide for cross-curricular teaching. In S. Humble (Ed.), *Creating the Coding Generation in Primary Schools* (pp. 176–186). Routledge. <https://www.taylorfrancis.com/chapters/edit/10.4324/9781315545813-16/kids-coding-computational-tinkering-david-miller-mark-horneff>
- Mills, K., Coenraad, M., Ruiz, P., Burke, Q., & Weisgrau, J. (2021). Computational Thinking for an inclusive world: A resource for educators to learn and lead. *Digital Promise*. <https://doi.org/10.51388/20.500.12265/138>
- Ministry of Education–Te Tāhuhu o te Mātauranga. (2007). *The New Zealand curriculum*. <https://newzealandcurriculum.tahurangi.education.govt.nz/>
- Mouza, C., Pan, Y.-C., Yang, H., & Pollock, L. (2020). A Multiyear Investigation of Student Computational Thinking Concepts, Practices, and Perspectives in an After-School Computing Program. *Journal of Educational Computing Research*, *58*(5), 1029–1056. <https://doi.org/10.1177/0735633120905605>

- National Centre for Education Statistics. (2023). *Table 325.35. Degrees in computer and information sciences conferred by postsecondary institutions, by level of degree and sex of student: Academic years 1964-65 through 2021-22*. https://nces.ed.gov/programs/digest/d23/tables/dt23_325.35.asp
- National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017*; Special Report NSF 17–310. National Science Foundation: Arlington, VA, USA. <https://nces.nsf.gov/pubs/nsf23315/>
- Ortiz-Martínez, G., Vázquez-Villegas, P., Ruiz-Cantisani, M. I., Delgado-Fabián, M., Conejo-Márquez, D. A., & Membrillo-Hernández, J. (2023). Analysis of the retention of women in higher education STEM programs. *Humanities & Social Sciences Communications*, *10*(1), 101–101. <https://doi.org/10.1057/s41599-023-01588-z>
- Page, S. E. (2019). *The diversity bonus: How great teams pay off in the knowledge economy*. Princeton University Press.
- Papavlasopoulou, S., Sharma, K., & Giannakos, M. N. (2020). Coding activities for children: Coupling eye-tracking with qualitative data to investigate gender differences. *Computers in Human Behavior*, *105*, 105939. <https://doi.org/10.1016/j.chb.2019.03.003>
- Passey, D. (2017). Computer science (CS) in the compulsory education curriculum: Implications for future research. *Education and Information Technologies*, *22*, 421–443. <https://doi.org/10.1007/s10639-016-9475-z>
- Prensky, M. (2001). Digital natives, digital immigrants Part 1. *On the Horizon*, *9*(5), 1–6. <https://doi.org/10.1108/10748120110424816>
- Román-González, Pérez-González, J.-C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. *Computers in Human Behavior*, *72*, 678–691. <https://doi.org/10.1016/j.chb.2016.08.047>
- Sharma, K., Torrado, J. C., Gómez, J., & Jaccheri, L. (2021). Improving girls' perception of computer science as a viable career option through game playing and design: Lessons from a systematic literature review. *Entertainment Computing*, *36*, 100387. <https://doi.org/10.1016/j.entcom.2020.100387>
- Spieler, B., Oates-Indruchová, L., & Slany, W. (2020). Female students in computer science education: Understanding stereotypes, negative impacts, and positive motivation. *Journal of Women and Minorities in Science and Engineering*, *26*(5), 473–510. <https://doi.org/10.1615/JWomenMinorScienEng.2020028567>
- Stephenson, C., Cooper, S., Boucher Owens, B., & Gal-Ezer, J. (2012). The new CSTA K-12 computer science standards. *Proceedings of the 17th ACM Annual Conference on Innovation and Technology in Computer Science Education*, 363–364. <https://doi.org/10.1145/2325296.2325380>
- Su, B. (2009). Effective technology integration: Old topic, new thoughts. *International Journal of Education and Development using ICT*, *5*(2). Open Campus, The University of the West Indies, West Indies. <https://www.learntechlib.org/p/188083/>
- Sullivan, A. (2021). Supporting girls' computational thinking skillsets: Why early exposure is critical to success. In M. Bers (Ed.), *Teaching Computational Thinking and Coding to Young Children* (pp. 216–235). IGI Global. <https://doi.org/10.4018/978-1-7998-7308-2.ch011>
- Sullivan, A., & Bers, M. U. (2013). Gender differences in kindergarteners' robotics and programming achievement. *International Journal of Technology and Design Education*, *23*, 691–702. <https://doi.org/10.1007/s10798-012-9210-z>

- Sun, L., & Liu, J. (2023). Different programming approaches on primary students' computational thinking: A multifactorial chain mediation effect. *Educational Technology Research and Development*, 557-584. <https://doi.org/10.1007/s11423-023-10312-2>
- Sun, L., Hu, L., & Zhou, D. (2022). Programming attitudes predict computational thinking: Analysis of differences in gender and programming experience. *Computers and Education*, 181, 104457. <https://doi.org/10.1016/j.compedu.2022.104457>
- Tapscott, D. (2009). *Grown up digital*. McGraw-Hill [e-book]. <https://www.getabstract.com/en/summary/grown-up-digital/11480>
- Tedre, M., Simon, & Malmi, L. (2018). Changing aims of computing education: a historical survey. *Computer Science Education*, 28(2), 158–186. <https://doi.org/10.1080/08993408.2018.1486624>
- Thompson, C. (2019). *The secret history of women in coding computer programming once had much better gender balance than it does today. What went wrong?* <https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html>
- Tiwari, S. P. (2022). Knowledge enhancement and understanding of diversity. *Technium Social Sciences Journal*, 30(1), 159–163. <https://doi.org/10.47577/tssj.v30i1.6311>
- U.S. Bureau of Labor Statistics (2020). *Women in the labor force: A databook (No. 1084)*. <https://www.bls.gov/opub/reports/womens-databook/2019/pdf/home.pdf>
- U.S. Bureau of Labor Statistics. (2023). *Labor Force statistics from the current population survey: household data annual averages. 11. employed persons by detailed occupation, sex, race, and hispanic or latino ethnicity*. <https://www.bls.gov/cps/cpsaat11.htm>
- United Nations. (n.d.). *Goals 5, Achieve gender equality and empower all women and girls*. <https://sdgs.un.org/goals/goal5>
- United Nations Education, Scientific and Cultural Organization [UNESCO]. (2018). *Telling saga: Improving measurement and policies for gender equality in science, technology and innovation sustainable development goals. Working paper 5. STEM and gender advancement (SAGA)*. <https://unesdoc.unesco.org/ark:/48223/pf0000266102>
- University of Houston. (2021). *Identity & academic motivation lab*. <https://uh.edu/education/iamlab/>
- Urhanne, D., & Wijnia, L. (2023). Theories of motivation in education: An integrative framework. *Educational Psychology Review*, 35(2), 45. <https://doi.org/10.1007/s10648-023-09767-9>
- Vaniček, J., Šimandl, V. (2020). Participants' Perception of Tasks in an Informatics Contest. In: Kori, K., Laanpere, M. (eds) Informatics in Schools. Engaging Learners in Computational Thinking. ISSEP 2020. *Lecture Notes in Computer Science*, vol 12518. Springer, Cham. https://doi.org/10.1007/978-3-030-63212-0_5
- Voogt, J., & Knezek, G. (Eds.). (2008). *International handbook of information technology in primary and secondary education (Vol. 20)*. Springer Science & Business Media [e-book]. <https://doi.org/10.1007/978-0-387-73315-9>
- Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, 20(4), 715–728. <https://doi.org/10.1007/s10639-015-9412-6>
- Wang, L. L., Stanovsky, G., Weihs, L., & Etzioni, O. (2021). Gender trends in computer science authorship. *Communications of the ACM*, 64(3), 78–84. <https://doi.org/10.1145/3430803>
- Webb, M., Davis, N., Bell, T., Katz, Y. J., Reynolds, N., Chambers, D. P., & Syslo, M. M. (2017). Computer science in K-12 school curricula of the 21st century: Why, what and when? *Education and Information Technologies*, 22(2), 445–468. <https://doi.org/10.1007/s10639-016-9493-x>

- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33–35. <https://doi.org/10.1145/1118178.1118215>
- Wing, J. M. (2018). Computational thinking's influence on research and education for all. *Italian Journal of Educational Technology*, 25(2), 7-14. <https://doi.org/10.17471/2499-4324/922>
- Witherspoon, E. B., Schunn, C. D., Higashi, R. M. & Baehr, E. C. (2016). Gender, interest, and prior experience shape opportunities to learn programming in robotics competitions. *International Journal of STEM Education* 3, 18. <https://doi.org/10.1186/s40594-016-0052-1>
- Zhang, S., & Wong, G. K. W. (2022). Cross-lagged associations between cognitive performance and attitudinal beliefs of Computational Thinking: A preliminary study, 2022 *IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, Hung Hom, Hong Kong (pp. 562-566). <https://doi.org/10.1109/TALE54877.2022.00098>
- Yamazaki, H., & Nishida, A. (2025). Analyzing gender differences in motivational drivers for pursuing careers in computing and technology fields. *Journal of Engineering and Technology Research*, 32(2), 45–62. <https://joetsr.com/wp-content/uploads/2025/09/JOETSR-Vol.32-2-October-2025.pdf>
- Ye, J., Lai, X., & Wong, G. K. W. (2022). A multigroup structural equation modeling analysis of students' perception, motivation, and performance in computational thinking. *Frontiers in Psychology*, 13, 8–17. <https://doi.org/10.3389/fpsyg.2022.989066>