FRANK BATTEN SCHOOL
of LEADERSHIP and PUBLIC POLICY

Bridging the Gender Gap in Computer Science Education in Virginia

Applied Policy Project
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Code VA

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Mandatory Disclaimer

The author conducted this study as part of the professional education program at the Frank Batten School of Leadership and Public Policy, the University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author and are not necessarily endorsed by the Batten School, the University of Virginia, or any other agency.

Acknowledgments and dedication

First and foremost, I thank Allah for granting me the strength, opportunity, and guidance to complete this project.

I am deeply grateful to Professor Daniel Player and Professor Sebastian Tello-Trillo for their continuous support, encouragement, and thoughtful feedback throughout the year. Their mentorship has shaped both my learning and my confidence.

To Tina Manglicmot, the Executive Director of CodeVA, thank you for welcoming me with such warmth and generosity. Your openness made this experience truly meaningful.

I would also like to thank my family and friends, whose love, belief in me, and constant encouragement have sustained me through every step of this journey. I could not have done this without them.

Finally, I carry this work with the memory and strength of Sudan, my home. Even amid war, its resilience and beauty live in me and push me forward.

Executive Summary

This report explores policy alternatives to increase female participation in high school computer science (CS) courses across Virginia. Despite a statewide CS education mandate, gender disparities persist, with girls remaining significantly underrepresented in advanced CS coursework. Drawing on national and state-level data, program cost estimates, and relevant research, this report proposes and evaluates three targeted interventions aimed at reducing these disparities:

- **Organizing Girls-Only Summer Camps and After-School Clubs**
  Builds on CodeVA's existing infrastructure to offer informal, interest-driven CS experiences in supportive environments before making high school tracking decisions.
- **Enhancing Teacher Preparedness to Deliver Inclusive CS Curriculum**
  Integrates gender-sensitive strategies into CodeVA's current professional development programs to help teachers create more welcoming and equitable classroom environments.
- **Expanding Access to Gamified Digital Tools**
  Reduces barriers to engaging CS instruction through platforms that increase student motivation and persistence, particularly among students who may feel intimidated by traditional CS instruction.

These alternatives were evaluated based on their relative cost, equity, feasibility, and time to impact. While each shows promise in different ways, I recommend prioritizing the implementation of the gender-sensitive teacher training module. This alternative stands out for its strong evidence of effectiveness, high feasibility, and low cost per student reached.

To ensure long-term success and sustainability, I recommend that CodeVA explore more partnerships with school divisions to embed the training into existing PD frameworks, seek targeted funding to support outreach to high-need districts, and continuously assess teacher feedback to refine the content over time.

Introduction

Over the past decade, computer science (CS) has become one of the fastest-growing fields in education and the workforce. Yet, despite growing national and statewide efforts to expand access to K–12 CS education, deep disparities persist, particularly along gender lines. In Virginia, where CS is mandated across K–12 education, girls continue to be significantly underrepresented in high school CS courses. This gender gap reflects more than a lack of interest or aptitude. It signals a broader pattern of exclusion rooted in classroom environments, teaching practices, early exposure, and access to informal learning opportunities.

This report was prepared for CodeVA, Virginia's leading nonprofit in K–12 computer science education, to evaluate and compare promising alternatives for increasing female participation in high school CS courses. The proposed interventions reflect a range of strategies, including enhancing teacher training, offering all-girls summer camps, and expanding access to gamified online tools. Each is assessed using a framework that incorporates cost-effectiveness, equity, feasibility, and time to impact.

Rather than advancing a single solution, this report aims to weigh tradeoffs and identify what is most likely to close gender gaps in CS education across diverse school contexts. By doing so, it seeks to inform CodeVA's efforts to build a more inclusive and equitable computer science landscape for Virginia's students.

Problem Statement

Despite being the first state to mandate computer science instruction across K–12, Virginia continues to see significant underrepresentation of girls in high school computer science courses. During the 2023–2024 school year, only 25.7% of high school CS students were girls (VDOE, 2024). Enrollment patterns across Virginia show that female representation remains disproportionately low even in well-resourced districts with high CS participation (VDOE, 2024). This suggests that expanding access alone is insufficient to close the gender gap. Deeper cultural and structural barriers, such as lack of encouragement, identity-based stereotypes, and how CS is framed, may shape who sees the field as "for them" (Master et al., 2021).

Client Overview

CodeVA is a nonprofit organization based in Virginia that works to expand equitable access to computer science (CS) education across the state. Founded in 2013, CodeVA partners with the Virginia Department of Education and school divisions to provide teacher training, curriculum development, and student programming aligned with state CS standards. The organization offers professional development for K–12 educators, advocates for inclusive CS policies, and supports informal learning through initiatives like summer camps and after-school coding programs.

A key part of CodeVA's mission is to ensure that CS is accessible to all students, especially those historically underrepresented in the field, including girls from underfunded schools and rural communities.

The gender gap in high school CS enrollment directly challenges CodeVA's goal of creating a more inclusive and representative computing pipeline. Despite the implementation of statewide computer science mandates, girls remain significantly underenrolled in computer science courses, even in schools where they are offered. This disconnect between access and participation reveals deeper structural and cultural barriers, barriers that CodeVA is uniquely positioned to address through its professional learning programs, school partnerships, and student-centered initiatives.

Addressing this issue now is especially urgent. With growing demand for CS skills and continued gender disparities in the tech workforce, early intervention at the high school level is critical. By focusing on gender equity in CS enrollment, CodeVA can shape who participates in CS today and who leads it in the future. Through this project, CodeVA can explore targeted, scalable strategies that move beyond access to foster belonging, motivation, and lasting engagement among girls across Virginia.

Defining the Problem

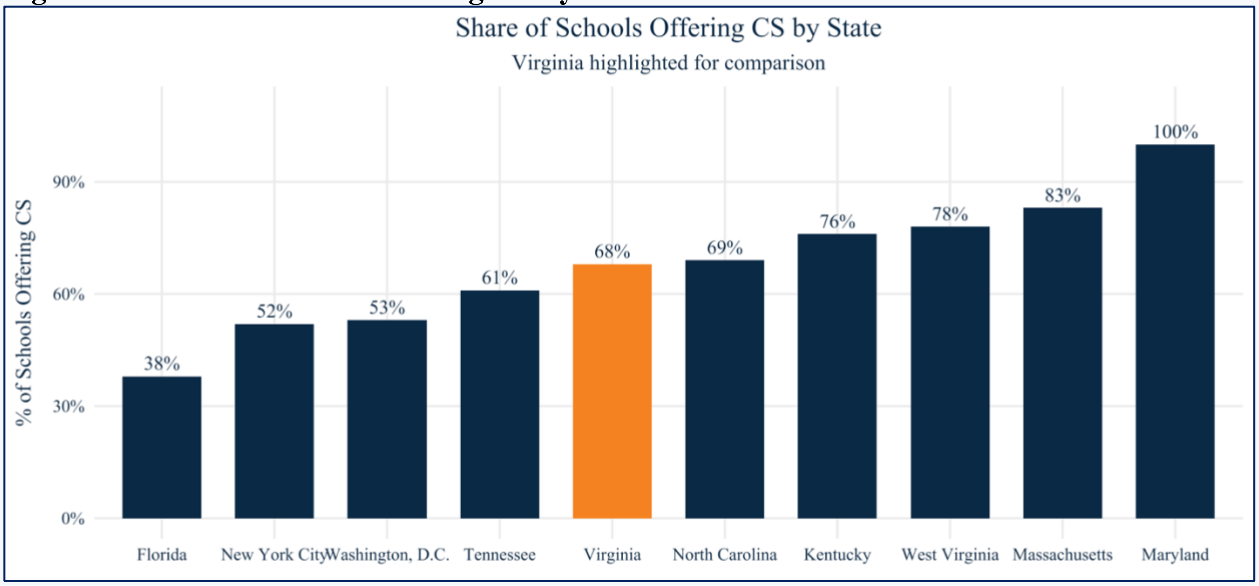
Overview of the Gender Gap in CS

Gender imbalance in computer science (CS) remains a persistent issue. Since the 1990s, CS has been the only science, technology, engineering, and mathematics (STEM) field where the percentage of women is declining (Corbett & Hill, 2015). The share of women receiving bachelor's degrees dropped from 27.0% in 1998 to 19.9% in 2018 (NCSES, 2021). These trends in degree attainment have downstream effects on the workforce, where women make up only 24% of all computer occupation roles (U.S. Department of Labor, 2022). A lack of gender diversity in tech can limit the range of perspectives in product design, reduce creativity, and reinforce systemic biases in emerging technologies (Singh et al., 2007; Criado Perez, 2019). Computer and information technology jobs are projected to grow significantly through 2033, offering over 350,000 job openings annually (Bureau of Labor Statistics, 2023). Despite rising demand for computing professionals, the continued underrepresentation of women in CS degree programs limits the pipeline of qualified female candidates.

This underrepresentation in higher education and the workforce can be traced back to earlier stages of the education pipeline, particularly in high school, where girls are already underrepresented in computer science courses. Nationally, women comprise only 32.5% of enrollment in foundational computer science courses, which are intro-level classes covering problem-solving, computing systems, and data. This underrepresentation nationally may be partly due to limited access, as only 60% of U.S. high schools offer foundational computer science courses. This gap in access is closely tied to socioeconomic status: high schools where more than 50% of students qualify for free or reduced-price lunch are significantly less likely to offer foundational CS courses. Moreover, computer science courses typically exist as elective offerings in U.S. high schools, meaning students must proactively opt in rather than automatically enroll. Socioeconomic barriers frequently intersect with racial disparities, deepening inequities. Even among the 32.5% of girls who enroll in CS, representation remains uneven: girls of color, particularly Black, Latina, and Indigenous students, are significantly less likely to participate compared to their white peers, further compounding gaps in representation (Code.org Advocacy Coalition et al., 2024).

Nationally, states vary widely in how much access they provide to foundational computer science education. As shown in Figure 1, Virginia sits near the middle, with 68% of high schools offering foundational CS courses, which is slightly above the national average (Code.org Advocacy Coalition et al., 2023). This statewide statistic, however, masks important disparities in access and enrollment within Virginia's school districts.

Figure 1. Share of Schools Offering CS by State



Source: Author's calculations based on data from the Virginia Department of Education (2024).

Overview of CS in Virginia

Virginia has expanded computer science education at the K–12 level. This section outlines the state's legislative mandates, curriculum standards, and Computer Science course enrollment trends in high schools.

1. State Mandates and Standards

Virginia was the first state to mandate the incorporation of computer science across K–12 education. In March 2016, the Virginia General Assembly passed House Bill 831 (HB831), which requires the Standards of Learning (SOL), Virginia's statewide academic standards that outline minimum expectations for student learning in each grade and subject, and local school division curricula to include computer science and computational thinking, including computer coding, from kindergarten through 12th grade (Virginia House Bill 831, 2016).

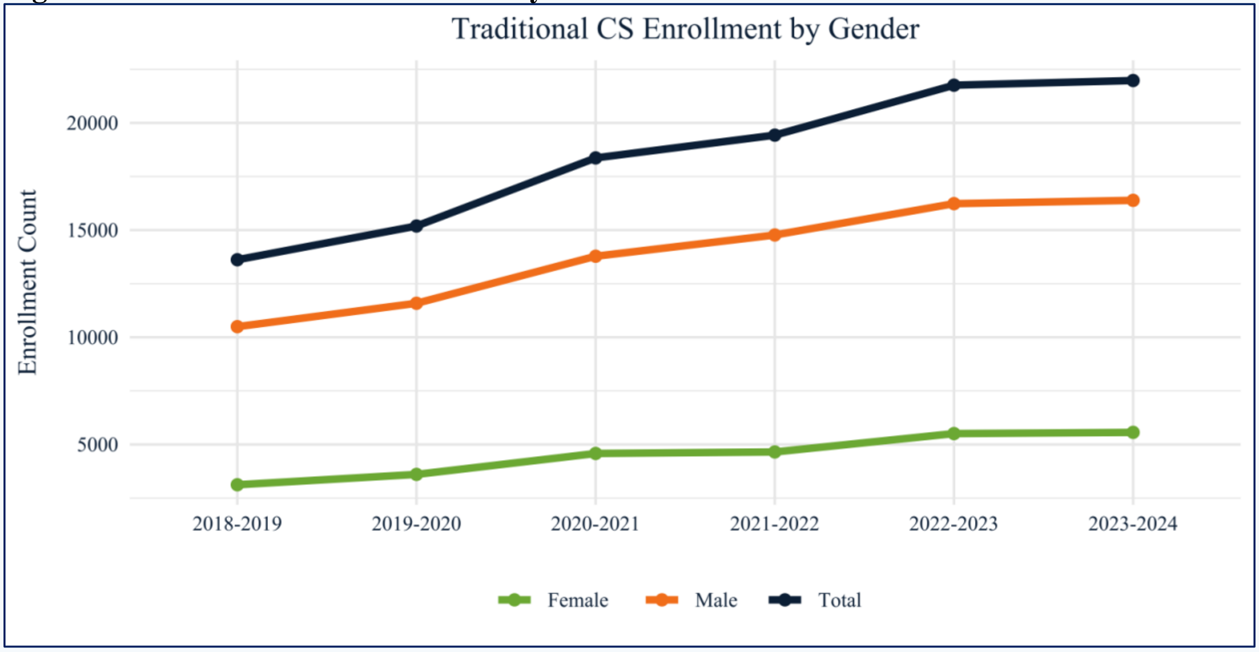
The Computer Science Standards of Learning for Virginia Public Schools were adopted in 2017. The standards identify the academic content of the computer science curriculum at different grade levels. Covering kindergarten through grade 8, with optional modules in middle school and a structured course sequence in high school. Content is divided into six strands: Computing Systems, Networks and the Internet, Cybersecurity, Data and Analysis, Algorithms and Programming, and the Impacts of Computing. Each strand builds in difficulty as students progress into high school grades. Even though the standards are numbered and grouped by topic, local school districts decide the order in which they are taught. The K–8 standards are developed to be woven into the subjects like math, science, history, English, fine arts, and technical education. Middle and high school electives are stand-alone; however, connections could be drawn to other subjects when relevant. High school standards allow students to apply computer science concepts in different real-world contexts. The standards are structured to represent a complete instructional framework and to show how students are expected to advance within each content strand. This structure also illustrates the step-by-step development of skills over time (VDOE, 2024a).

Although Virginia's Computer Science Standards were developed with equity as a central goal, they acknowledge that equitable access requires more than simply offering courses. Ensuring meaningful participation involves inclusive instruction, intentional recruitment, and a supportive classroom culture (VDOE, 2024a). With this in mind, examining enrollment trends, particularly in high school, can provide insight into whether these equity goals are being met.

2. Student-Level Enrollment Trends in High School CS Courses

Enrollment in traditional computer science courses in Virginia high schools, such as AP Computer Science A, AP Computer Science Principles, and introductory programming, has steadily increased. However, this growth has not been equally distributed across all student demographics. Female enrollment, in particular, has seen only modest gains over the past five years. For instance, although girls now make up roughly 25% of students in these courses, this figure has remained relatively flat, increasing by only a few percentage points since 2018.

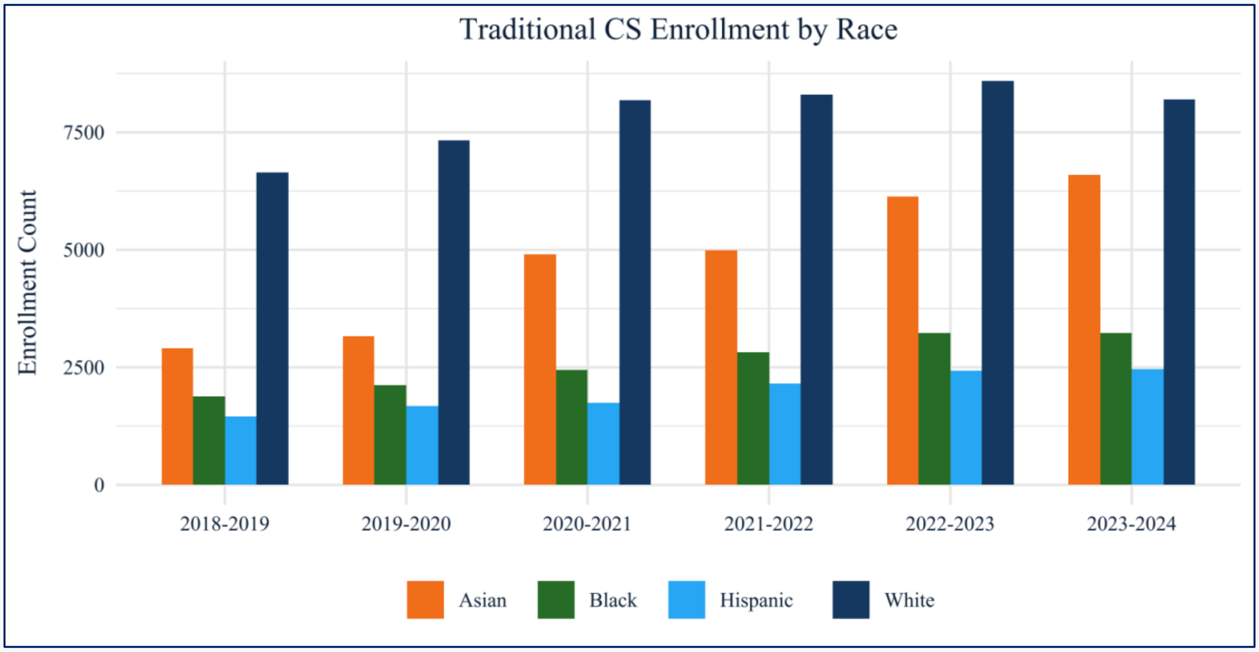
Figure 2. Traditional CS Enrollment by Gender



Source: Author's calculations based on data from the Virginia Department of Education (2024).

While this report focuses on gender disparities in CS, enrollment patterns also reveal persistent racial and ethnic inequities. As shown in Figure 3, White and Asian students continue to make up the majority of students in traditional CS courses, while Black and Hispanic students remain significantly underrepresented. These trends point to structural barriers that may overlap with those faced by girls, particularly girls of color.

Figure 3. Traditional CS Enrollment by Race



Source: Author's calculations based on data from the Virginia Department of Education (2024).

3. District-level Enrollment Trends for High School CS Courses

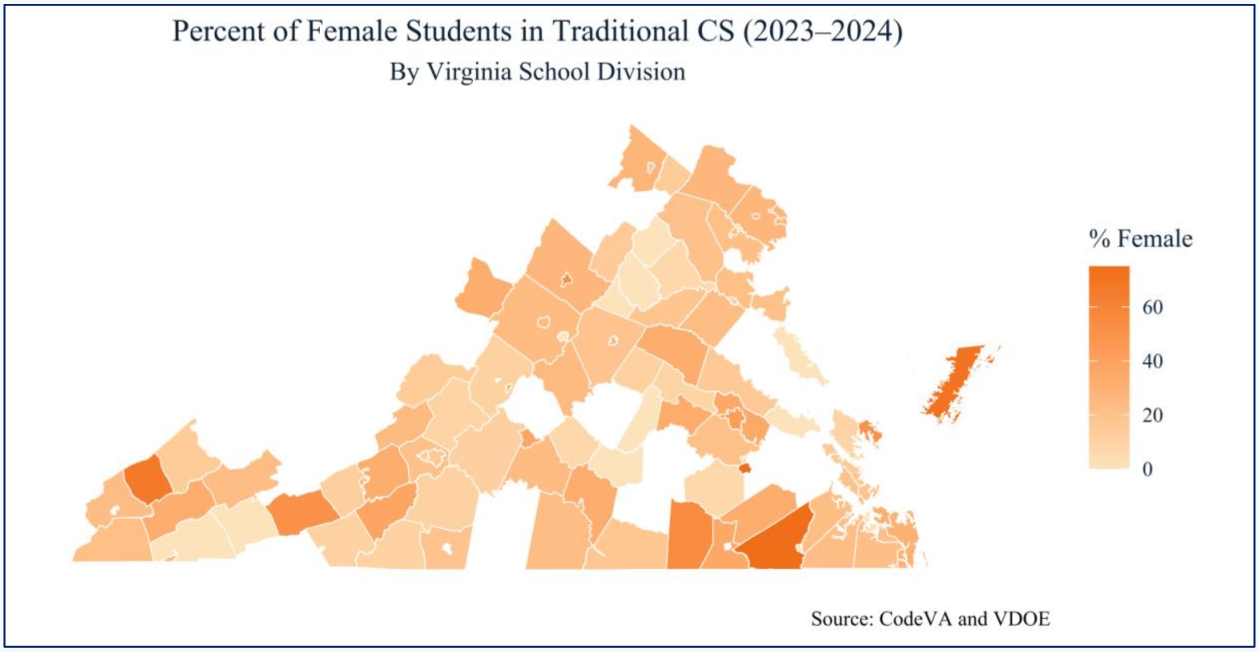
Analyzing enrollment trends at the district level reveals important nuances in how computer science (CS) education is accessed and experienced across Virginia. While some divisions report relatively high percentages of female participation, these figures can be misleading without context, particularly in districts with low overall CS enrollment. In such cases, a small number of female students may appear as a high percentage, even though meaningful access and representation remain limited. Additionally, missing or inconsistent data across some divisions limits the completeness of the statewide picture.

The heat map below shows the percentage of female students in high school CS courses across Virginia's school divisions during the 2023–2024 academic year. Darker shades indicate higher female representation, while lighter shades reflect lower participation. Most divisions fall within the 0 to 20 percent range, highlighting the widespread underrepresentation across the state.

These patterns suggest that gender disparities are not solely a function of course availability or district size. Instead, they may reflect differences in local outreach, instructional practices, and broader cultural or structural barriers that influence whether students see CS as accessible or relevant. Simply offering CS courses, while necessary, is not sufficient to ensure equitable participation.

For example, Fairfax County Public Schools, the ninth-largest district in the United States and the highest in total CS enrollment in Virginia, reports that only 25 percent of its CS students are female. This illustrates that gender gaps persist even in large, well-resourced divisions and reinforces the need for intentional recruitment and retention strategies beyond access alone.

Figure 4. Female Representation in High School Computer Science Enrollment by School Division, Virginia (2023–2023)



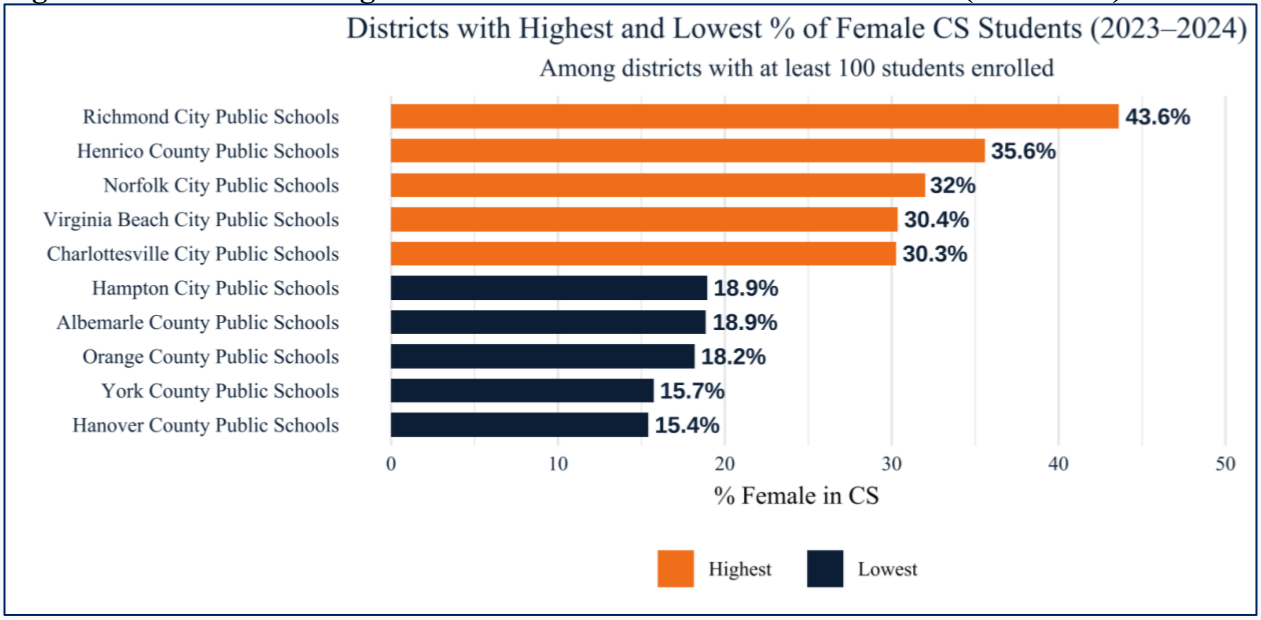
Source: Author’s calculations based on data from the Virginia Department of Education (2024).

A closer look at the divisions with the highest and lowest female representation reveals additional patterns. Most divisions with higher female participation are located in urban or suburban areas, where families may have greater access to resources, higher levels of parental education, and stronger institutional support systems. These conditions can create environments more conducive to encouraging girls to explore and persist in computer science. However, the group varies widely in terms of wealth. Richmond City, a high-need urban division, reports one of the highest rates at 43.6 percent. In contrast, divisions such as Henrico and Virginia Beach, both well-resourced suburban systems, also perform relatively well. This diversity indicates that higher female participation is possible across different socioeconomic contexts and may be more closely tied to local leadership, school culture, and intentional outreach than income level alone.

There is a noticeable pattern when considering division size. Districts with higher female representation tend to be large or mid-sized, while those with the lowest representation are more often small or mid-sized. This trend suggests that larger districts may benefit from greater resources, staffing, and program infrastructure, which can support broader participation in computer science. In contrast, smaller divisions may struggle with limited course offerings, fewer specialized teachers, and reduced capacity for targeted outreach.

These findings clearly highlight disparities between districts in Virginia and point to the need for a qualitative investigation to better understand the reasons behind these differences.

Figure 5. Districts with Highest and Lowest % of Female CS Students (2023-2024)



Source: Author's calculations based on data from the Virginia Department of Education (2024).

Potential Explanatory Factors

While enrollment data highlight disparities in female participation in high school computer science courses, they do not fully explain the underlying causes. Understanding why these gaps persist requires considering a range of contextual, structural, and cultural factors. This section outlines several potential explanations informed by observed patterns and existing literature, including classroom culture, early exposure, and the difference between access and encouragement.

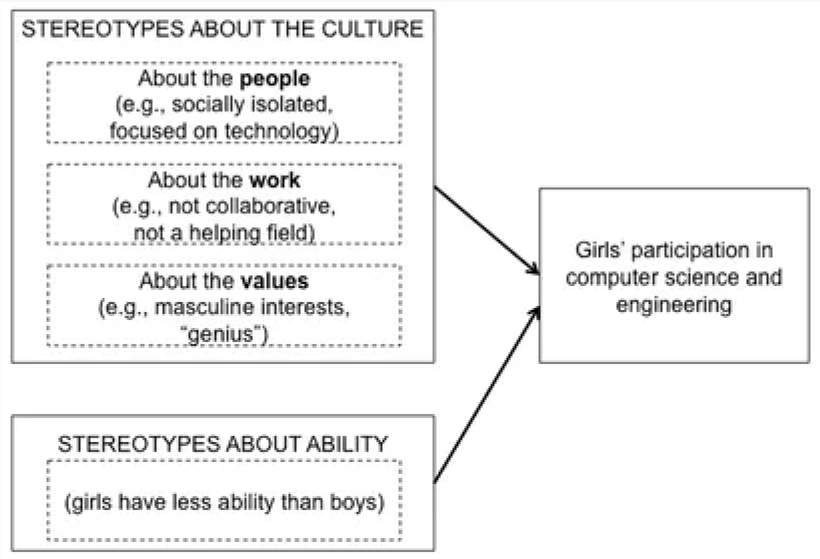
1. The Early Roots of Gender Disparities in CS

A growing body of research highlights that gender disparities in computer science (CS) often take root long before high school, well before students are asked to opt in. As early as age six, children form beliefs about intelligence and who belongs in intellectually demanding fields. In a peer-reviewed study published in *Science*, Bian et al. (2017) found that girls at this age were already less likely than boys to associate brilliance with their gender. This perception directly influenced their interest in intellectual activities, including computing. Building on this, Master et al. (2021) found that children as early as first grade already endorse stereotypes suggesting that girls are less interested than boys in computer science. These perceptions of lower interest may be a byproduct of the earlier stereotypes about brilliance. Together, these early messages shape whether girls see CS as "for them," long before course enrollment becomes a decision point.

While these identity-based barriers begin early, they persist throughout the educational pipeline. High school interventions must therefore account for the fact that many girls may view CS as unwelcoming or misaligned with their interests, even when courses are available.

When students reach high school, boys often arrive in CS classrooms with years of informal experience gained through games, self-guided exploration, or digital tinkering. In contrast, many girls encounter CS for the first time in formal classroom settings. This “experience gap,” described by Margolis and Fisher (2001), not only undermines confidence but also shapes classroom dynamics, where students with prior exposure tend to dominate discussions and set the pace. For girls entering without that background, it can reinforce the sense that CS is not for them, even before the first lesson begins.

Figure 6. Cultural Stereotypes as Gatekeepers.



The figure was adapted from Cheryan, Master, & Meltzoff (2015)

2. Classroom Culture

Even when CS courses are available and well-staffed, female participation remains disproportionately low in many Virginia school divisions. This suggests that barriers extend beyond access and stem from how students experience these classrooms once enrolled.

Teachers’ influence extends beyond content delivery to include the expectations they set, the environments they create, and the ways they engage students. A wide-scale survey from Google & Gallup (2016) found that male students were significantly more likely than female students to report being told by a teacher that they would be good at computer science (39% vs. 26%). These differences in encouragement may reflect unconscious biases that shape who feels seen and supported in CS learning environments. Therefore, for girls who do opt in, classroom culture can reinforce the very stereotypes they have internalized since early childhood. Messages like “boys are better at programming” or perceptions that CS is a “boys’ club” often manifest subtly through who dominates discussions, who gets praised, or how success is defined.

These dynamics can make girls feel isolated, out of place, or less competent, even if their performance is equal. Sometimes, the absence of other female students or the lack of inclusive design can push them to drop the course.

Implications for Intervention

The analysis shows that increasing access to computer science courses is a necessary but insufficient step toward gender equity. While Virginia has made CS instruction widely available, the persistent underrepresentation of girls, even in high-enrollment and well-resourced districts, suggests that deeper, structural barriers limit participation. Girls are not opting out of CS simply because it is unavailable; many opt out even when offered.

It is important to recognize that the gender gap in computer science could be partially explained by differences in preferences and interests, rather than solely by inequitable access and opportunity. However, research suggests that these preferences are themselves shaped by early exposure to gender stereotypes and limited opportunities.

These findings suggest that effective interventions must go beyond course provision. They must address how CS is introduced, who it appears to be for, and what kind of environment students encounter when they arrive. Interventions that focus on shaping early exposure, reframing course recruitment practices, and supporting teachers to foster more inclusive and identity-safe learning spaces are most likely to move the needle.

Literature Review

While various interventions have been proposed to address gender disparities in computer science, much of the existing evidence is observational, qualitative, or based on small-scale studies. Few studies use experimental methods to isolate the causal impact of specific interventions such as early exposure, inclusive teaching, or informal learning opportunities. Nevertheless, the literature offers valuable insights into participation patterns and promising strategies that consistently correlate with increased interest and engagement among girls in CS.

Teachers as Gatekeepers

Teachers play a significant role in shaping whether girls feel welcome, encouraged, and capable in computer science classrooms. Teachers influence the physical and cultural tone of the classroom, both of which affect girls’ willingness to participate. Master et al., 2016 found that high school girls were more likely to express interest in an introductory CS course when the classroom was decorated in a non-stereotypical way (e.g., nature posters, art supplies, and lamps) rather than in a stereotypical one (e.g., video games, science fiction décor, and electronics). Sixty-eight percent of girls preferred the non-stereotypical classroom, compared to only 48 percent of boys. Girls' interest in the stereotypical classroom was no different from their baseline, suggesting that many already expect CS spaces to be unwelcoming. Their interest increased significantly when presented with a new, more inclusive vision of what computer science could look like. These findings underscore that even subtle design decisions often made by teachers can signal whether girls "belong" in CS and may influence their decision to enroll.

Teacher capacity and effectiveness in delivering computer science instruction significantly influence student outcomes. Using a potential outcome modeling approach and comparing 167 participating schools with matched comparison schools, one study found that the gains were especially pronounced for female and minority students. A causal evaluation of Code.org's year-long teacher training program, which used statistical matching methods, showed that trained teachers increased the number of girls taking the Advanced Placement (AP) Computer Science A (CSA) exam and their performance. The effect size for girls' participation was a 5.28 percentage point increase in enrollment (Browm & Brown, 2019).

In addition, teachers and school staff can influence who enrolls in advanced CS courses through proactive and inclusive recruitment strategies. One notable example is a "buddy system" implemented at South Brunswick High School, which allowed female students to choose classmates to enroll with in upper-level CS (Schiff & Frees, 2023). The initiative was designed to foster belonging and reduce isolation, and it led to a doubling of female enrollment in the most advanced CS course. While the study is based on a single school and lacks a comparison group, its simplicity and outcome suggest that teacher-facilitated peer enrollment strategies may offer a scalable way to increase equity in CS participation.

Creative Pedagogies for Engaging Girls

The instructional strategies used in CS education also affect student engagement and persistence, especially for girls. Gamified activities, real-world applications, and collaborative learning have emerged as promising ways to improve participation.

Gamification and game-based learning use game-like features (like points, levels, or challenges) to make learning more engaging and effective. These methods are based on the idea that people learn best by doing and interacting with others, especially in digital environments. Game-based learning uses these tools strategically to reach specific educational outcomes (York & deHaan, 2018).

Gamified learning platforms can also help reduce the intimidation often associated with learning CS by embedding foundational concepts into low-stakes, playful environments. A meta-analysis by Sailer and Homner (2020) found that gamification significantly enhances motivational outcomes, with an average effect size of $g = 0.36$ across 16 studies. According to Cohen's (1988) interpretation of standardized mean differences, this represents a 14–15% increase in student motivation, a critical predictor of academic engagement, persistence, and achievement, especially in challenging subjects like computer science (Davis et al., 2018; Chang & Wei, 2016).

Additional studies support the potential of game-based tools to drive engagement. Bernal et al. (2018) evaluated the impact of Chatbot, a tool that allows students to build conversational agents, across both classroom pilots and a national online competition. Among 10,000 participating students, those using Chatbot completed tasks at five times the rate of peers using traditional animation software. Girls demonstrated higher engagement indicators, suggesting that well-designed gamified tools may help reduce gender gaps in CS participation.

While promising, gamification is not without its limitations. Some studies suggest that its effectiveness may be partly driven by novelty, with motivational gains decreasing over time as students become accustomed to the gamified format (Sharma et al., 2021). This highlights the importance of ongoing refinement and intentional integration to sustain impact over the long term.

The Role of Informal Learning and Role Models

While formal computer science instruction is critical in shaping students' academic pathways, informal learning opportunities such as robotics competitions, coding clubs, and summer coding programs often lay the foundation for early interest and confidence. There is a clear need to create informal opportunities intentionally designed to engage girls. These could include beginner-friendly summer camps, girls-only coding clubs, robotics competitions, and hackathons. Such spaces allow girls to build skills, gain confidence, and develop a sense of belonging outside traditional classroom settings.

Research also concludes that the lack of female role models in computer science discourages women from these fields (Eccles 2007). While female role models in computer science are widely considered important, research suggests that not all role models are equally effective. What matters most is whether students perceive a sense of similarity with the role model. Cheryan et al. (2011) found that women reported greater anticipated success in computer science when introduced to non-stereotypical female role models whose personalities or interests felt more relatable. This sense of perceived similarity mediated their motivation, suggesting that simply seeing a woman in the field is not always enough. Similarly, Stout et al. (2011) found that female students who related more to female faculty reported higher self-efficacy in math. These findings indicate that effective role modeling requires intentionality, ensuring that girls see someone who looks like them and reflects their values, goals, or personality.

Evidence from a multi-year study of STEM summer camps for middle and high school girls shows that participation significantly improved students' confidence in their technical skills (Reed et al., 2022). Camp participants scored significantly higher on technology self-efficacy than non-participants, with a Cohen's d effect size of 0.73, indicating a substantial positive impact. Although the program did not immediately shift career intentions, the findings support the value of early exposure, particularly when paired with mentorship, collaborative learning, and ongoing reinforcement.

A study by Seshan et al. (2022) evaluated the impact of a Girls Who Code (GWC) club hosted at the University of Southern Indiana. Using a Computer Science Attitude Survey, the researchers assessed changes in participants' confidence, interest in CS, and perceptions of gender-related stereotypes. The results indicated that approximately 80% of participants were fairly certain they would major in CS, and over 90% felt confident in their ability to succeed academically in the field. The club fostered a supportive environment that helped shift perceptions of CS from male-dominated to inclusive. For example, 100% of participants agreed that girls are just as capable as boys in programming, and 92.9% strongly agreed they would trust a girl just as much as a boy to solve programming problems. Qualitative feedback highlighted a sense of "sisterhood," enjoyment, and increased interest in pursuing CS long-term.

Synthesis: Key Lessons for CodeVA

The literature clarifies that advancing gender equity in computer science requires more than increasing access. Interventions must also reshape how girls experience and engage with the subject. While teacher training, gamified tools, and informal learning each show promise, the strength and nature of their evidence vary.

Teacher PD has the strongest causal backing but depends heavily on implementation and school support. Informal programs and gamified tools show potential to boost motivation and belonging, though their evidence base is less robust and often correlational.

Each approach operates at a different level, instruction, curriculum, or access point, bringing scalability, cost, and timing trade-offs. Summer camps may offer quick gains in confidence, but are harder to scale; gamified tools scale more easily but may yield slower impact.

No single strategy will close the gender gap. Sustainable change requires layered solutions integrating pedagogy, relevance, and inclusion. CodeVA should prioritize approaches that do all three.

Criteria

Below is a description of the criteria used to evaluate the alternatives presented in this report, along with a brief justification for each. These criteria were selected to reflect the values and priorities of CodeVA and its partners, balancing considerations of cost, equity, feasibility, and time to impact. Please refer to Annex X for the detailed point system used to assess each criterion.

Cost

In this analysis, cost refers to the financial expenses incurred by CodeVA to implement each proposed alternative. The focus is on direct operating costs, such as personnel, materials, space rental, meals, and stipends. These were estimated using program-specific data provided by CodeVA, prior budgets, publicly available salary scales, and vendor rates.

Fixed costs, including infrastructure or capital investments, are assumed to be negligible across all alternatives, as none require new facilities or equipment.

To ensure a consistent comparison, all costs are expressed as per-student estimates which is calculated by dividing the total projected cost by the expected number of students directly served. For simplicity, we assume that all alternatives will serve 100 students in the first year. However, the teacher training alternative could reach more students due to its indirect impact through educators.

Each alternative's total cost was calculated using available data and informed assumptions based on CodeVA's past programming. For example, summer camp costs included curriculum development, facilitator stipends, student lunches, and administrative overhead. The teacher training alternative included consultant fees, training material updates, and teacher incentives. Costs for gamified tools were based on licensing fees and minimal training requirements, using average prices from the K–12 edtech market.

In direct programming models (e.g., summer camps), the number of students served was known. For teacher-focused interventions, student reach was estimated by multiplying the number of trained teachers by the average number of students taught annually. For instance, in the teacher training scenario, each of 25 teachers was assumed to reach 21.6 students, yielding 540 students' total. This is aligned with NCES data on class sizes in departmentalized high school instruction (NCES, 2020). A detailed breakdown of all costs is provided in the Cost Appendix.

Cost-effectiveness

Cost-effectiveness refers to how efficiently a program achieves its intended outcomes relative to its cost. This report calculates the dollar amount required to produce one measurable unit of change, such as an additional student enrolling in a CS course or a percentage-point increase in student motivation. This metric allows for comparisons across alternatives based on total cost and the value delivered per dollar spent (Fermanich, 2021).

Due to inconsistencies in available causal research, the measured outcomes differ across interventions. As a result, this criterion was assigned the least weight. When scoring this category, the strength of the supporting literature was also considered to account for these variations in evidence quality.

Equity

- CodeVA's mission is to deliver computer science education to all children in Virginia. This criterion aligns with their organizational mission by ensuring that all girls. The equity score evaluates how well each alternative addresses disparities in access to computer science (CS) education across four key dimensions:
- **Support for Underfunded Schools**: Alternatives receive higher scores if they prioritize resource-limited schools and offer financial or logistical support to reduce barriers. Programs that fail to mention underfunded schools receive the lowest score, while those providing targeted support and subsidies receive the highest.
- **Geographic Inclusivity**: This dimension assesses whether the alternative is designed to reach students and teachers across all regions of Virginia, including rural and remote communities. Strategies that include regional outreach or leverage existing networks score higher, while those limited to urban centers or centralized delivery score lower.
- **Gender Equity**: Alternatives are evaluated on the extent to which they are intentionally designed to increase participation among female students. Programs that merely encourage inclusivity score lower, while those with specific outreach, tailored content, or design features aimed at addressing gender disparities receive higher scores.

- **Flexibility of Engagement**: This assesses how accessible the program is for participants with scheduling or logistical constraints. Alternatives that require in-person attendance with little flexibility score lower, while those that offer online, hybrid, or asynchronous participation options receive the highest marks.

Ease of Implementation

As a small nonprofit, CodeVA has limited staff and resources, so evaluating the complexity of implementation is crucial. An alternative that requires many moving parts, external partnerships, or extensive staff involvement may be harder to execute effectively The Ease of Implementation score reflects how practical and feasible it is to carry out each alternative, based on four dimensions: infrastructure needs, stakeholder interest, policy alignment, and scalability. Each dimension is described below:

- **Infrastructure Requirements**: This assesses the extent to which the alternative depends on new or existing infrastructure and staff. Alternatives that require building new systems or hiring large numbers of staff score lower.
- **Stakeholder Interest and Adoption Likelihood**: This dimension evaluates how likely schools, teachers, and administrators are to adopt the intervention. Alternatives with limited interest or competing priorities score lower, while those with strong existing partnerships or high buy-in potential score higher.
- **Legal and Bureaucratic Feasibility**: This assesses how well the alternative aligns with existing education policies and whether it may face legal or administrative obstacles. Programs with major regulatory barriers score lower, while those aligned with current policies and frameworks score higher.
- **Scalability**: This evaluates whether the alternative can be expanded beyond a pilot program. Alternatives that are difficult to replicate or limited in geographic reach score lower, while those that can grow using CodeVA's current partnerships, networks, and tools receive the highest scores.

Time to Impact

The Time to Impact score assesses how quickly each alternative is likely to produce measurable outcomes in increasing female participation in computer science (CS) courses. Each alternative is rated on a scale from 1 to 3 based on the estimated timeframe within which meaningful change can reasonably be observed:

- **Score of 1 (Low)**: The alternative is likely to require multiple years before observable changes occur, either due to its indirect approach or the age of the target population. For example, interventions targeting elementary students may not affect high school CS enrollment for several years.
- **Score of 2 (Moderate)**: The alternative is expected to produce measurable changes within one to two years. These interventions typically engage students close to the point of course selection or indirectly influence decision-making through educators or parents.

- **Score of 3 (High)**: The alternative will likely generate observable changes within the same academic year. These interventions typically target high school students already making enrollment decisions or provide tools to teachers positioned to implement changes immediately.

Evaluating Alternatives

To address the persistent gender gap in high school computer science (CS) enrollment, this set of alternatives targets one or both of the most critical leverage points in the participation pipeline: *recruitment* and *retention*. Data analysis shows that girls remain under-enrolled even when CS courses are offered, suggesting that access alone is insufficient. The three alternatives aim to disrupt this cycle by focusing on the moments when girls decide whether CS is "for them" and the conditions that shape their experience after they opt in.

Alternative 1: Expand Informal Learning Opportunities for Girls in CS

This alternative proposes organizing two-week, girls-only summer coding camps with year-long after-school clubs for elementary and middle school students. These informal, interest-driven experiences aim to spark and sustain girls' engagement in computer science by providing low-pressure, supportive environments for exploration, skill-building, and identity development. Programs of this kind have boosted girls' confidence and interest in computing, particularly when implemented before high school tracking decisions are made (Master et al., 2016).

Focusing on girls through grade 8 allows the program to intervene early, before social and academic barriers shape students' perceptions of who belongs in CS. After-school clubs would provide continuity throughout the academic year, helping to reinforce interest through peer support and ongoing engagement.

Logistically, this will involve four summer camps (5 days each, 6 hours per day), each serving approximately 25 students, for 100 participants. All camps will follow the same curriculum, adjusted for complexity based on age, but with a similar implementation structure. Camps will be delivered in separate cohorts to ensure high-quality instruction and manageable group sizes. CodeVA will identify and collaborate with the schools participants attend to establish after-school girls' coding clubs, providing some material support to help them launch and sustain the clubs.

Cost

This alternative receives a score of 1 (Low). The total cost for the first year is $47,223, resulting in a per-student cost of $472. The program is expected to serve 100 students across four 5-day summer sessions, each capped at 25 participants. The cost estimate includes curriculum development, staff training, facilitation, student lunches, and intern stipends.

Cost-Effectiveness

This alternative receives a score of 3 (High) based on substantial evidence for potential impact. To estimate effectiveness, I draw on the 2021 external evaluation of the Girls Who Code Summer

Immersion Program (SIP), which used a matched comparison design to assess the program's long-term effects on postsecondary outcomes. The study found that participants were 13.2 percentage points more likely to major in computer science in college than their comparable peers. While this outcome reflects a later-stage effect, it necessarily implies increased high school CS course participation, which research has shown to be a strong predictor of CS majoring (Liu, Conrad, and Blazar, 2024).

The proposed intervention targets high school enrollment directly, positioning it earlier in the pipeline and potentially yielding even greater near-term effects. However, to remain conservative and ensure comparability, I use the 13.2 percentage point increase as a reference for estimating impact.

At a cost of $472 per student, this results in a cost-effectiveness estimate of approximately $35 per percentage point increase in the likelihood of majoring in computer science.

Equity

This alternative receives a score of 2 (moderate). It partially advances equity by specifically targeting girls in underfunded schools and aiming to improve gender representation in computer science. However, several limitations constrain its full equity potential.

The proposed $35 registration fee is intended to promote commitment but may create a financial barrier for low-income students unless paired with a clear scholarship or fee-waiver option. The program includes four summer sessions: two in Richmond and two at existing CodeVA hubs. CodeVA's current network of regional Hub Partners includes the Institute for Advanced Learning and Research in Danville, Chesterfield County Public Schools, Harrisonburg City Public Schools, Loudoun County Public Schools, and others. Leveraging this network helps broaden geographic access but may not fully remove participation barriers for students in remote or underserved areas.

Finally, the absence of hybrid or virtual participation options reduces flexibility, which may exclude students with transportation challenges or family responsibilities that limit their ability to attend in person.

Ease of implementation

This alternative receives a score of 3 (High). CodeVA has prior experience running similar programs, including day camps primarily based in Richmond, and already possesses the infrastructure, curriculum, and staffing models needed to support this type of initiative. The organization is well-versed in the logistical and instructional demands of informal CS learning environments, which reduces the need for extensive planning or training.

Moreover, multiple school divisions have previously partnered with CodeVA to organize summer camps for their students, demonstrating strong stakeholder interest and trust. Because these programs operate outside the traditional school year, they are less likely to encounter significant bureaucratic hurdles or require direct oversight from the Virginia Department of Education. This alternative is also highly scalable. CodeVA's existing network of regional Hub Partners can be leveraged to expand programming across different localities with minimal additional structural investment. Its track record and relationships with districts suggest that the model can be replicated in other areas without major administrative or logistical barriers.

Taken together, CodeVA’s operational capacity, prior experience, and established partnerships make this alternative both feasible and scalable with relatively low effort.

Time to Impact

This alternative receives a score of 2 (Moderate). The summer camp component may generate immediate benefits in the form of increased interest and confidence among participating middle school girls. However, because the primary goal is to influence high school CS enrollment, measurable outcomes will not be visible for several years. This delay limits the short-term visibility of impact. That said, the inclusion of after-school coding clubs helps sustain interest beyond the summer and offers a structure for ongoing engagement within students’ school environments.

Alternative 2: Enhancing Teacher Preparedness to Deliver Inclusive CS Curriculum

CodeVA can strengthen its efforts to increase equitable participation in computer science (CS) by developing a targeted, gender-sensitive professional development (PD) module for teachers. Research shows that teacher-held stereotypes and unconscious biases can unintentionally discourage girls from pursuing CS by reinforcing traditional gender roles, shaping classroom dynamics, and influencing who feels encouraged to enroll (Goode, Estrella, & Margolis, 2013; Google & Gallup, 2016).

To address these barriers, CodeVA could implement a specialized training module that equips teachers with tools to recognize bias, create inclusive classroom environments, and intentionally recruit underrepresented students. This could be paired with a toolkit for teachers that includes sample course guide language, posters or flyers with inclusive messages, and peer-led testimonial templates. The module could incorporate evidence-based strategies such as bias-free course descriptions, inclusive classroom design (Master et al., under review), and tools like the “buddy system” (Schiff & Frees, 2023), which have been shown to increase girls’ enrollment in CS courses.

Instead of embedding this content into certification prep programs such as Praxis Prep or GUTS, which often serve teachers still early in their CS teaching, CodeVA could target this intervention to high school educators who are already offering CS courses and experiencing enrollment disparities. A practical option would be to offer this module as a stand-alone short course or as a specialized equity-focused track within Coaching Async. This approach ensures the training reaches teachers who are in a position to implement these strategies immediately and supports CodeVA’s broader mission to close equity gaps in CS education across Virginia.

Cost

This alternative receives a score of 3 (High). The proposed in-person workshop is expected to train 25 teachers, each representing a different school. The total cost of $15,549 results in a per-student cost of $29. This estimate assumes that each trained teacher will reach an average of 21.6 students, based on national data for elementary school class sizes in the United States. Across 25 teachers, this results in a total annual reach of approximately 540 students (NCES, 2020). The cost estimate includes consultant fees, course material updates, facilitation, teacher incentives, and administrative overhead.

Cost - Effectiveness

This alternative receives a score of 2 (Moderate). To estimate effectiveness, I draw on Tate et al. (2019), who evaluated a teacher professional development program in computer science using a matched comparison design. The study found that schools with trained teachers saw an average increase of 5.28 female students enrolling in CS courses. Assuming each trained teacher yields a similar effect, the proposed intervention could lead to approximately 132 additional female students participating in CS annually.

At a total cost of $15,549, this results in a cost-effectiveness estimate of approximately $118 per additional female student enrolled in computer science. In other words, for every $118 invested, the program is expected to support one more girl enrolling in a high school CS course during the first year.

Tate et al. (2019) provides moderate evidence for expected impact. The study uses a matched comparison design and directly measures changes in female CS enrollment, making it a relevant and credible benchmark. However, the findings may not generalize fully to all contexts, and the actual impact may vary based on teacher engagement and school implementation.

Equity

This alternative receives a score of 2 (Moderate). It is designed to reach educators across Virginia, including those in underfunded and rural school divisions, through an accessible online training model. However, the in-person workshop component may pose a barrier, as it requires teachers to travel to Richmond. This limits flexibility and may disadvantage teachers from remote or low-resource areas unless travel support is provided.

To ensure the training reaches schools where gender disparities are most pronounced, CodeVA can use enrollment data to identify high-need divisions and prioritize outreach to their teachers. This could include targeted invitations, direct engagement through regional coaches, or partnerships with division leaders to encourage participation.

The training content itself focuses on gender-sensitive and bias-aware pedagogy, directly addressing classroom-level barriers that disproportionately affect girls in CS. While the intervention includes intentional strategies to improve gender equity, it lacks fully flexible engagement options and may not remove all access barriers for under-resourced educators, which justifies the moderate equity rating.

Ease of implementation

This alternative receives a score of 3 (High). It is relatively easy to implement due to CodeVA's existing infrastructure and experience delivering professional development programs. The training is delivered both online and through an in-person workshop held in Richmond, which simplifies coordination compared to school-based or district-wide rollouts. CodeVA already has the staff, administrative systems, and logistical capacity needed to support this format.

Integrating gender-sensitive content into existing training modules requires only minor curriculum modifications, rather than developing an entirely new program. This reduces development time and supports faster implementation.

There is a strong likelihood of adoption. CodeVA has previously partnered with school divisions across Virginia to deliver professional development, and this training aligns closely with its mission to advance equity in computer science education. While some teachers may face competing PD priorities, targeted outreach and modest incentives can help encourage participation.

Scalability is moderate. Although the in-person component limits immediate reach, the model can be replicated in other regions through CodeVA's existing network of facilitators and partner organizations. With additional investment and coordination, the program could be expanded to serve more educators across the state.

Time to impact

This alternative receives a score of 3 (High). It targets teachers across K–12, who are expected to begin applying the tools from the new gender-sensitive module within weeks or months. These tools are intended to help improve classroom environments and support proactive strategies for recruiting girls into computer science courses. The benefits of the training are expected to be self-sustaining, as teachers continue to implement inclusive practices and share knowledge with peers over time.

Alternative 3: Engaging Girls Through Gamified and Accessible Coding Tools

This alternative proposes expanding access to student-friendly, gamified online coding platforms (e.g., Tynker, CodeMonkey) in Virginia middle and elementary school classrooms, with potential extension into high school computer science (CS) courses. By providing educators and students with high-quality digital tools at no cost, this approach aims to enhance the learning experience, sustain student interest, and improve retention in CS pathways.

Online platforms that use game design elements, such as storytelling, competition, and real-time feedback have been shown to increase student engagement, foster computational thinking, and create more interactive and inclusive classroom environments (citation). These tools can be especially valuable in schools with limited CS teaching resources, enabling students to explore programming in a more accessible and playful way.

Focusing on integration in the middle and elementary years supports early exposure and sustained interest during a critical period when students begin forming their academic identities. Expanding access to these platforms at the high school level can also help retain students in CS courses by making the content more engaging and relevant.

Logistically, CodeVA would license or subsidize classroom-ready tools for schools with limited budgets and provide basic training for teachers on how to incorporate the platforms into existing CS courses. Special emphasis should be placed on reaching underfunded and rural schools to promote equity in access.

Cost

This alternative receives a score of 2 (Moderate). The total annual cost of implementation is estimated at $5,059, serving approximately 100 students, resulting in a cost per student of $51. This includes licensing costs, teacher onboarding, and limited technical support.

Cost-Effectiveness

This alternative receives a score of 2 (Moderate). To estimate effectiveness, I draw on Sailer and Homner's (2020) meta-analysis on gamification in education, which found that gamified tools have a moderate positive effect on student motivation, with an effect size of $g = 0.36$. Based on standard interpretations of effect sizes (Cohen, 1988), this corresponds to an estimated 14–15% increase in motivation. Using this estimate, the cost per 10-percentage-point increase in motivation is approximately $37. This suggests that for every $37 invested, the program is expected to generate a meaningful gain in motivation. Research consistently shows that motivation is a key predictor of academic engagement, persistence, and achievement, especially in challenging subjects like computer science (Davis et al., 2018; Chang & Wei, 2016). While this alternative does not directly measure its impact on CS course enrollment, improvements in student motivation are likely to increase retention.

Equity

This alternative receives a score of 2 (Moderate). It expands access by providing students in underfunded schools with free or subsidized tools to learn foundational computer science skills. By reducing cost barriers, the program promotes broader participation in CS education. However, the tools themselves are designed for general audiences and do not specifically address gender inclusivity. Without targeted strategies to engage girls, such as inclusive content, representation, or recruitment support, the program may not fully close gender gaps in participation. In addition, although the platforms support self-paced learning, students with limited access to computers, reliable internet, or adult guidance may struggle to benefit fully from the tools.

Overall, while this alternative promotes equity through access and affordability, the lack of tailored support for underrepresented groups and variability in home access limits its full equity potential.

Ease of implementation

This alternative receives a score of 3 (High). Because it does not require significant new infrastructure or staffing, it is relatively easy to implement. The online coding tools already exist, and CodeVA's role would primarily involve securing access for students and teachers. This could be done through partnerships with platform providers or by purchasing licenses for underfunded schools.

Additionally, these tools are self-paced and teacher-friendly, requiring minimal training for educators to integrate them into their classrooms. Teachers can use them as supplementary learning resources, which reduces the burden of developing new instructional content. According to guidance from the Virginia Department of Education (VDOE), school divisions are encouraged to use a limited number of high-quality digital solutions for communication, teaching, and learning. Based on this guidance, it is reasonable to expect high uptake of the tools among educators. Furthermore, students can access the tools independently, either at school or at home, which increases both flexibility and reach.

Time to impact

This alternative receives a score of 2 (Moderate). It is designed for students in elementary and middle school, which means that measurable impact on high school computer science enrollment would take at least one year. For example, students in the final year of middle school would not enter high school until the following academic year, making one year the minimum timeframe to observe effects.
CodeVA will follow up with teachers on a monthly basis to ensure that students are engaging with the tools and to gather feedback on teachers' perceptions of the platforms.

Outcome Matrix

Alternative	Cost (Weight =20%)	Cost-Effectiveness (Weight =15%)	Equity (Weight =25%)	Ease of Implementation (Weight =20%)	Time to Impact (Weight =20%)	Total (Percentage Score (%))
Expanding After-School and Summer Initiatives for Girls	1	3	2	3	2	72%
Enhancing Teacher Preparedness to Deliver Inclusive CS Curriculum	3	2	2	3	3	86.7%
Engaging Girls Through Gamified and Accessible Coding Tools	2	2	2	3	2	73.3%

Recommendation

This report recommends that CodeVA prioritize implementing a gender-sensitive professional development (PD) module for teachers. This alternative received the highest overall score when evaluated across cost, cost-effectiveness, equity, ease of implementation, and time to impact. While it does not lead in every category, it offers the most balanced trade-off across all criteria and is highly feasible to implement in the short term.

The teacher training module stands out for its ease of implementation and quick timeline to impact. It builds on CodeVA's existing infrastructure and partnerships with school divisions, requires only minor adjustments to current training content, and can begin influencing classroom environments within weeks. Although the evidence base is moderate, it is directly tied to student enrollment outcomes, unlike other options focusing more on indirect drivers such as motivation. However, the success of this approach depends on teacher engagement and consistent application of the training content. To strengthen its impact, CodeVA should consider offering modest incentives for participation and building in regular follow-up to reinforce inclusive practices.

Implementation

Approval and Proposal Development

To launch the gender-sensitive professional development (PD) module, CodeVA would begin with internal approval in the summer of 2025. The leadership team and the senior director of programs would develop the project proposal, identify funding strategies, allocate staff time to support curriculum development and create a detailed implementation plan. The curriculum leads would prepare a brief draft of the new content to be developed. Financial staff would create a budget and review the module's compatibility with current grants and organizational priorities. The completed proposal would then be presented to CodeVA's board to ensure consensus.

Securing Funding

After the board approves the proposal, the fundraising team at CodeVA will seek funding to support the design and delivery of the PD module. As a nonprofit with experience managing education grants, CodeVA is well-positioned to pursue a combination of public and private funding sources.

At the state level, CodeVA could apply for grants through the Virginia Department of Education (VDOE), particularly those focused on computer science education and equity. Programs like the Virginia K–12 Computer Science Education Grant may directly support curriculum development and teacher training. CodeVA could also collaborate with VDOE to advocate for the inclusion of the training module in future state budget proposals. At the same time, CodeVA would engage private philanthropic funders with an interest in advancing STEM equity.

The estimated timeline for securing funding is two to three months, based on typical VDOE grant review and award schedules. However, this timeframe could be shorter depending on the specific grant program and funding cycle.

Curriculum Design

Once approved, CodeVA would hire a consultant with expertise in computer science education and equity to co-develop the professional development module. The curriculum would incorporate evidence-based strategies such as bias-free course descriptions, inclusive classroom design, proactive recruitment techniques, and classroom tools like the buddy system. Supplementary materials would include sample outreach messages, posters, and student testimonial templates that teachers could use to promote their courses.

The estimated timeline for curriculum development is two to three months. During this period, the draft module would be reviewed by CodeVA's faculty team and presented to a group of educators to gather feedback and make revisions as needed.

Outreach and Engagement

In parallel with curriculum development, CodeVA would identify school divisions with significant gender disparities in computer science enrollment using data from the Virginia Department of Education. The partnership supervisor and partnership lead would develop an outreach plan to ensure that teachers in the most in-need schools are reached. This plan would include creating new partnerships or revisiting existing ones to strengthen engagement and expand the program's reach.

Pilot Rollout

The first cohort would launch in the spring of 2026, beginning with approximately 25 high school teachers from a diverse mix of school divisions, including rural and underfunded areas. The training would be delivered through a hybrid model, combining a one-day in-person workshop in Richmond with asynchronous online learning components. Teachers would complete pre- and post-training surveys to evaluate awareness, knowledge, and classroom readiness shifts. CodeVA would also collect qualitative feedback to assess content clarity and usefulness.

Iteration and Expansion

Following the pilot, CodeVA would revise the training based on participant feedback. Updates could include clarifying instructions, adding more examples, or improving usability better to serve a broader range of educators in future cohorts.

Ongoing Monitoring and Support

To sustain impact, CodeVA would offer optional follow-up coaching sessions to trained teachers once per semester. These check-ins would reinforce key practices and provide space for peer collaboration and troubleshooting. CodeVA would also work with partner divisions to monitor changes in gender enrollment trends in CS courses. This ongoing evaluation would inform future program improvements and support long-term planning around CS equity efforts across the state.

Conclusion

Gender disparities in high school computer science enrollment reflect broader structural barriers in access, inclusion, and early exposure to computing. While Virginia has made progress in expanding CS education, participation remains uneven, particularly for girls and students from historically underrepresented groups. This report presents a set of feasible, cost-effective, and equity-oriented interventions that CodeVA and its partners can pursue to address this gap. Each alternative offers a unique lever to improve outcomes, from targeted teacher training to informal learning programs and gamified digital tools. Closing the gender gap in computer science will require intentional investment, collaboration, and a willingness to center students who have long been left out of the field.

References

Bian, L., Leslie, S. J., & Cimpian, A. (2017). Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science*, *355*(6323), 389–391. https://doi.org/10.1126/science.aah6524

Brown, R., & Brown, E. (2019). Estimating the causal effect of a teacher training program on Advanced Placement® outcomes. *International Journal of Computer Science Education in Schools, 2*(4), 3–10. https://doi.org/10.21585/ijcses.v2i4.35

Bureau of Labor Statistics, U.S. Department of Labor. (2023). *Occupational outlook handbook, computer and information technology occupations*. https://www.bls.gov/ooh/computer-and-information-technology/home.htm

Chang, J. W., & Wei, H. Y. (2016). Exploring engaging gamification mechanics in massive online open courses. *Journal of Educational Technology & Society, 19*(2), 177–203. https://eric.ed.gov/?id=EJ1097207

Cheryan, S., Drury, B. J., & Vichayapai, M. (2013). Enduring influence of stereotypical computer science role models on women's academic aspirations. *Psychology of Women Quarterly, 37*(1), 72–79. https://doi.org/10.1177/0361684312459328

Code.org Advocacy Coalition, Computer Science Teachers Association, & Expanding Computing Education Pathways Alliance. (2024). *2024 State of computer science education: Understanding our national imperative*. Code.org. https://advocacy.code.org/stateofcs/

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Corbett, C., & Hill, C. (2015). *Solving the equation: The variables for women's success in engineering and computing*. American Association of University Women.

Criado Perez, C. (2019). *Invisible women: Data bias in a world designed for men*. Abrams Press. https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=2030243&site=ehost-live&scope=site

Davis, K., Sridharan, H., Koepke, L., Singh, S., & Boiko, R. (2018). Learning and engagement in a gamified course: Investigating the effects of student characteristics. *Journal of Computer Assisted Learning, 34*(5), 492–503. https://doi.org/10.1111/jcal.12254

Eccles, J. S., Barber, B., & Jozefowicz, D. (1999). Linking gender to educational, occupational, and recreational choices: Applying the Eccles et al. model of achievement-related choices. In W. B. Swann, J. H. Langlois, & L. A. Gilbert (Eds.), *Sexism and stereotypes in modern society: The gender science of Janet Taylor Spence* (pp. 153–191). American Psychological Association. https://doi.org/10.1037/10277-006

Fermanich, M. (2021). Introduction to cost-effectiveness analysis [Brief]. Region 5 Comprehensive Center. https://eric.ed.gov/?id=ED617087

Goode, J., Estrella, R., & Margolis, J. (2013). Lost in translation: Gender and high school computer science. In J. Cohoon & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 89–114). MIT Press.

Liu, J., Conrad, C., & Blazar, D. (2024). *Computer science for all? The impact of high school computer science courses on college majors and earnings* (EdWorkingPaper No. 24-904). University of Maryland. https://edworkingpapers.com/sites/default/files/ai24-904.pdf

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669–685. https://doi.org/10.1080/09500690902792385

Margolis, J., & Fisher, A. (2001). *Unlocking the clubhouse: Women in computing*. MIT Press.

Master, A., Meltzoff, A. N., & Cheryan, S. (2021). Gender stereotypes about interests start early and cause gender disparities in computer science and engineering. *Proceedings of the National Academy of Sciences, 118*(48), e2100030118. https://doi.org/10.1073/pnas.2100030118

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology, 108*(3), 424–437.

Maryska, M., Doucek, P., & Kunstová, R. (2012). The importance of ICT sector and ICT university education for the economic development. *Procedia - Social and Behavioral Sciences, 55*, 1060–1068. https://doi.org/10.1016/j.sbspro.2012.09.578

National Science Foundation. (2023). *Women, minorities, and persons with disabilities in science and engineering* (NSF 23-315). National Center for Science and Engineering Statistics. https://www.nsf.gov/reports/statistics/diversity-stem-women-minorities-persons-disabilities-2023

Reed, A., Wimmer, H., Boldyreff, C., & Kelly, M. (2022). Using STEM camps to improve female interest in technology careers. *Information Systems Education Journal, 20*(6), 15–24. https://files.eric.ed.gov/fulltext/EJ1459016.pdf

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*(1), 77–112. https://doi.org/10.1007/s10648-019-09498-w

Salac, J., Thomas, C., Butler, C., & Franklin, D. (2021). Understanding the link between computer science instruction and reading & math performance. University of Chicago; Texas State University. Retrieved from https://jeansalac.github.io/docs/ITiCSE2021_CSonReadMath.pdf

Schiff, S., & Frees, S. (2023). *A practical approach to increasing female enrollment in advanced computer science courses*. Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 2 (SIGCSE 2023), 1166–1166. Association for Computing Machinery. https://doi.org/10.5555/3636988.3637004

Seshan, M., Schikora, K., Feller, C., & Bailey, R. (2022). A survey-based evaluation of the efficacy of a Girls Who Code club at USI. *SC22: International Conference for High Performance Computing, Networking, Storage and Analysis*, 1–4. https://doi.org/10.1109/SC22.2022.10007227

Singh, K., Allen, K. R., Scheckler, R., & Darlington, L. (2007). Women in computer-related majors: A critical synthesis of research and theory from 1994 to 2005. *Review of Educational Research, 77*(4), 500–533. http://www.jstor.org/stable/4624909

Stout, J. G., Dasgupta, N., Hunsinger, M., & McManus, M. (2011). STEMing the tide: Using ingroup experts to inoculate women's self-concept and professional goals in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology, 100*, 255–270.

Stuart E. A. (2010). Matching methods for causal inference: A review and a look forward. Statistical science : a review journal of the Institute of Mathematical Statistics, 25(1), 1–21. https://doi.org/10.1214/09-STS313

U.S. Department of Labor, Women's Bureau. (2022). *Women in STEM: Occupational data*. https://www.dol.gov/agencies/wb/data/occupations-stem

Virginia Department of Education. (2024). *2023–2024 annual legislative report on CodeVA*. https://rga.lis.virginia.gov/Published/2024/RD541/PDF

Virginia Department of Education. (2024). High school computer science enrollment data by gender and race, 2023–2024 [Unpublished dataset]. Provided to CodeVA upon request.

Virginia Department of Education. (2024a). Computer science standards of learning for Virginia public schools. https://www.doe.virginia.gov/home/showpublisheddocument/53433/638469738558370000

Virginia House Bill 831, H.B. 831, Gen. Assemb., Reg. Sess. (Va. 2016).

York, J., & deHaan, J. W. (2018). A constructivist approach to game-based language learning: Student perceptions in a beginner-level EFL context. *International Journal of Game-Based Learning, 8*(1), 19–40. https://doi.org/10.4018/IJGBL.2018010102

Appendices

Appendix A: Data Overview

This project uses school-level computer science (CS) enrollment data provided by the **Virginia Department of Education (VDOE)** for the 2023–2024 academic year. The dataset includes total enrollment counts disaggregated by gender and race for each public high school in the state. It was provided directly to CodeVA by VDOE and is not publicly available.

The primary variables used in the analysis include:

- **School name and district**
- **Total number of students enrolled in CS courses**
- **Number of female students enrolled in CS courses**
- **Number of male students enrolled in CS courses**
- **Student enrollment by race/ethnicity**

Using this dataset, I calculated the percentage of female students enrolled in CS and examined variation across school divisions. I also linked the data to a shapefile of Virginia school districts for geographic mapping. The analysis was conducted using R, and descriptive statistics were used to highlight patterns in gender disparities. Data cleaning included filtering to only include traditional computer sciences classes and ensuring consistent variable formats across datasets.

Appendix B: Sensitivity Analysis

To assess the robustness of the recommendation, a sensitivity analysis was conducted by slightly adjusting individual criterion scores across the alternatives. Specifically, we examined how the overall rankings would change if one or two criteria were increased or decreased by one point from the original estimates. Across all reasonable adjustments, the gender-sensitive teacher training alternative consistently remained either the top-ranked or tied for the top-ranked option.

For example, we assumed that CodeVA might be able to secure funding for all three alternatives, eliminating cost as a differentiating factor. When we set the cost score to 3 for each option, the proposed teacher training alternative still led in the overall ranking.

Conversely, increasing the equity score of the gamified tools alternative or the effectiveness score of the summer camps option by one point did not meaningfully alter the final rankings. While these alternatives show promise, their lower scores in cost or delayed timelines prevent them from outperforming the teacher training module in most scenarios.

This analysis suggests that the recommendation to implement the gender-sensitive PD module is not overly dependent on any single score. Its strength lies in consistently strong performance across multiple criteria, demonstrating a high level of policy robustness.

Appendix C: Cost

Alternative 1: Expand Informal Learning Opportunities for Girls in CS					
Four Summer Camps (6 hour per day, and 5 days each) targeting 25 students each					
TOTAL COST			$47,223		
Cost Per Student (Students Served: 100)			$472		
Pre-camps (Course content development + Interns trainings)					
	Item	Type	Cost per item/per hour	Number of items	Total cost for item
	Student Summer Camp Course Development (25 hours)	Hourly	$325	$25	$8,125
	Consultation with gender inclusion experts	Per Item	$120	$7	$840
	Intern Prep Course Revision (Async and in-person)	Flat rate	$2,918	$1	$2,918
	Intern Prep Program facilitators fees x 2 facilitators	Hourly	$61	$18	$1,098
	Printed Training Materials or Intern Kits	Per Item	$0.71	$400	$284
	Intern lunch (3 days on intern training days)	Per Item	$15	$22	$330
	CodeVA Facilitation for interns (3 days - 2 facilitators)	Flat rate	$3,300	$1	$3,300
Implementation (Camp Delivery)					
	Facilitator Accommodation	Per Day	$150	$10	$1,500
	Facilitator Travel	Flat rate	$1,000	$1	$1,000

	Student Lunches ($5/day × 25 students × 10 days)	Per Day ($5 for student)	$125	$20	$2,500
	Facilitators per diem fees	Per Day	$157	$10	$1,570
Facilitation and interns cost					
	Computer Science High School Intern stipends (120h per volunteer)	Per Day ($12.41 per hour)	$1,489	$5	$7,446
	CodeVA Facilitation (1 facilitator for each camp)	Hourly	$113	$120	$13,560
Coding Clubs (School Year)					
	Clubs Materials and Printing	Flat rate	$750	$1	$750
	Student incentives (stickers, shirts)	Flat rate	$500	$1	$500
	Club advisor stipend	Flat rate	$2,000	$1	$2,000
Admin Cost					
		Director	**IP Supervisor**	**Part Supervisor**	**Ed Part Lead**
	Marketing and Outreach	1	0.5	2	1
	Program Logistics	2	15	10	1
	Faculty	0.5	4		
	Evaluation & Reporting	2.5	4	2	1
	Total hours	6	23.5	14	3
	Hourly cost	$94	$74	$36	$65
	Total cost for each staff	$564	$1,739	$504	$195
Registration fees					
	Fees per student	Flat rate	$35	100	3500
Alternative 2: Enhancing Teacher Preparedness to Deliver Inclusive CS Curriculum					

TOTAL COST			**$15,549**		
Cost Per Student (15549/(25 x 21.6))			**$29**		
Course adjustment					
	Item	**Type**	**Cost per item**	**Number of items**	**Total cost for item**
	Consultant – Content Development	Hourly	$150	30	$4,500
	Course Materials Update (Slides, PDFs, LMS)	Flat rate	$1,561	1	$1,561
Outreach cost					
	Outreach Materials (email + event flyers)	Hourly	$199	1	$199
	Tabeling	Hourly	$199	4	$796
	conferences	Per conference	$597	5	$2,985
In person workshop (Richmond)					
	Facilitator Fees	Hourly	$113	6.00	$678
	Space Rental	Hourly	$125	6.00	$750
	Teacher Incentives	Per teachers	$50	25.00	$1,250
	Snacks & Refreshments	Per participant	$8	25.00	$200
Admin Cost					
		Director	**IP Supervisor**	**Part Supervisor**	**Ed Part Lead**
	Marketing and Outreach	5	0.5	1	6
	Program Logistics	0.5	6	2	3
	Faculty	0.5	4		
	Evaluation & Reporting	2.5	4		1

	Total hours	8.5	14.5	3	10
	Hourly cost	$94	$74	$36	$65
	Total cost for each staff	$799	$1,073	$108	$650

Estimated impact based on 25 trained teachers, each assumed to represent a different school and reach an average of 21.6 students per year, consistent with average U.S. class sizes
in departmentalized instruction (NCES, 2020).

Alternative 3: Expanding Access to Free or Low-Cost Online Coding Tools					
TOTAL COST			**$5,059**		
Cost Per Student			**$51**		
School year plan fees (Tynker)					
	Item	**Type**	**Cost Per Student**	**Number of students**	**Total for Students**
	Full Academic year Plan	Per Item	$20	100	$2,000
Online training for teachers					
	Content development (consultant fees)	Hourly	$150	8	$1,200
	Facilitators fees (6 hours online training)	Hourly	$113	$6	$678
Admin Cost					
		Director	**IP Supervisor**	**Part Supervisor**	**Ed Part Lead**
	Marketing and Outreach	1	3	1	
	Program Logistics	0.5	1		1
	Faculty	0.5			
	Evaluation & Reporting	2.5	4		1

	Total hours	4.5	8	1	2
	Hourly cost	$94	$74	$36	$65
	Total cost for each staff	$423	$592	$36	$130

Appendix D: Criteria

Critria	1	2	3
	Weight 1	**Weight 2**	**Weight 3**
	The alternative is rated Low if the sum of points is 1	**The alternative is rated Moderate if the sum of points is 2**	**The alternative is rated High if the sum of points is 3**
Cost (Out of 3)	Cost per student is $200 and higher.	Cost per student is between $100 and less than $200.	Cost per student is less than $100.
	The alternative is rated Low if the sum of points is 1-2	**The alternative is rated Moderate if the sum of points is 3-4**	**The alternative is rated High if the sum of points is 5-6**
Cost-effectivness (Out of 3)	Cost per impact is $200 and higher.	Cost per student is between $50 and less than $200	Cost per student is less than $50.
	Limited evidence of impact.	Moderate evidance for expected impact	Strong evidance for potential impact
	The alternative is rated Low if the sum of points falls between 1-4	**The alternative is rated Moderate if the sum of points falls between 5-8**	**The alternative is rated High if the sum of points falls between 9-12**
Equity (Out of 12)	No efforts to include underfunded schools.	Includes underfunded schools but does not fully remove barriers.	Prioritizes underfunded schools and provides financial/resource support.
	No efforts to ensure geographic inclusivity	Includes some strategies but may not fully address rural barriers.	Designed for all regions, with targeted outreach and support for rural students.
	No consideration of gender equity.	Encourages gender inclusivity but lacks targeted strategies	Specifically designed to increase female participation, with tailored outreach/support.
	No flexible engagement options	Some flexibility but requires in-person elements.	Fully flexible, with online, hybrid, and asynchronous options.

	The alternative is rated Low if the sum of points falls between 1-4	The alternative is rated 1 if the sum of points falls between 5-8	The alternative is rated High if the sum of points falls between 9-12
Ease of Implementation (Out of 12)	Requires entirely new infrastructure.	Requires some new resources but mostly uses available infrastructure.	Requires minimal new resources; implemented with existing infrastructure/staff.
	Low likelihood of adoption due to lack of interest or competing priorities.	Some interest from stakeholders, with moderate effort needed for buy-in.	Strong stakeholders interest, with existing partnerships or high likelihood of adoption.
	Major legal or bureaucratic hurdles that may prevent implementation.	Minor policy challenges but can be addressed easily.	No significant barriers; aligns with existing policies.
	Difficult to replicate beyond initial pilot.	Can be expanded with moderate effort	Easily scalable using existing partnerships and resources

	The alternative is rated Low if the sum of points falls between 1-2	The alternative is rated Moderate if the sum of points falls between 3-4	The alternative is rated High if the sum of points falls between 5-6
Time to Impact (out of 6)	Requires more than 2 years before meaningful impact is seen	Takes 1–2 years for results to become clear.	Immediate impact (within weeks or months).
	Impact fades quickly without continued intervention.	Requires frequent follow-ups to sustain benefits.	Self-sustaining impact with long-term benefits.