WOMEN & GIRLS IN COMPUTING

One size won't fit all

A collaboration of

STUDENT RESEARCH foundation

&

The Research Consortium on STEM Career Pathways

AAPT PHYSICS EDUCATION

Girls Collaborative Project

NAPE

DESTINATION IMAGINATION

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Executive Summary

Between 2018 and 2028, the U.S. workforce will grow by 5.2%. The computing/IT sector will grow even more – 12.7%. Yet continued underrepresentation of women in the computing sector (26%) will reduce the talent pool and jeopardize the nation's ability to fill these high-skilled, high-paying jobs. Will a new generation transform the computing sector?

High school students' career aspirations foreshadow the future. This report analyzes data from a 2018 national survey of high school students, conducted by the Student Research Foundation. 74,149 students responded. Their attitudes identify prospects for gender equity and insights for interventions.

Key Findings

Girls who aspire to computing differ from males who aspire to computing *and* girls who aspire to non-computing fields. When the focus is girls and STEM, "one-size-won't-fit-all."

The Gender Gap. Among high school students aspiring to computing careers, boys outnumber girls 4:1. Moreover, the girls score lower on STEM confidence than boys – yet are more likely to be "A" students.

STEM Confidence. The already small segment of girls currently interested in computing is vulnerable.

- The gender gap in STEM confidence is greater among students who aspire to computing careers than among those who aspire to non-computing STEM fields or to non-STEM fields.
- Female computing aspirants have lower STEM confidence than males who aspire to computing and females who aspire to non-computing STEM careers.
- Female computing aspirants' confidence rivals that of girls who do not aspire to STEM careers.

Fairness. Female computing career aspirants are less confident they will be treated fairly in STEM classes than key comparison groups: male computing aspirants, females aspiring to STEM fields outside of computing, and females aspiring solely to non-STEM careers.
Interests. Girls who aspire to computing are substantially more likely than non-aspirants to also be interested in art (51% vs. 19%). While the increasing relevance of digital skills to art may broaden the path to computing among girls, this possible new path creates unique needs.

New paths, new needs. Among girls who aspire to STEM careers, computing career aspirants are less likely than non-aspirants to rate teachers, parents, and school activities as positive influences on their STEM interest. This lower influence is concentrated among female aspirants interested in art.

Urgency for action. By 2020, 94% of STEM careers will require education beyond high school. Among girls who aspire to STEM careers, computing career aspirants are more likely than non-aspirants to be uncertain about postsecondary education. That uncertainty is concentrated among girls who combine computing career aspirations with interest in art – the same sector less likely to rate adults and school activities as positive influences on STEM interest. Their uncertainty about postsecondary education increases the likelihood their talents will be lost to the sector when they graduate from high school.

Conclusion

Greater emphasis on what computing can do to make a difference in the world holds promise of attracting more girls and women to the sector. But once interested, adults and educational institutions are needed to support them on the new path – closing the gender gap in STEM confidence, increasing confidence of fair treatment in STEM classes, and mentoring students so they can navigate the path to professional life. This will benefit individuals, and it will benefit the U.S. economy. Yet as we craft those interventions, this analysis shows that it is critical to remember for workforce diversity as for life, "one-size-won't-fit-all."

Introduction

STEM professionals are in demand – especially in the computer and IT sector.

That sector is expected to grow by 13 percent between 2018 and 2028, adding new, high-skilled, high-paying jobs to the US economy.[1] Add to that vacancies created by retirement of the Baby Boomers, and the need for computing professionals becomes even clearer.

The ability of the United States to meet this growing demand is jeopardized by the sector's failure to fully tap the talents of women.[2]

- Women are 47% of the labor force, but hold only 26% of the jobs in computer occupations.[3]
- Women earn 57% of Bachelor's Degrees, but only 19% of degrees awarded in computer science and information technology.[4]
- Women's presence in the sector has *declined* over the last three decades,[5] even as the number of jobs in the sector has increased.[6]

This is vividly illustrated in the graph below.

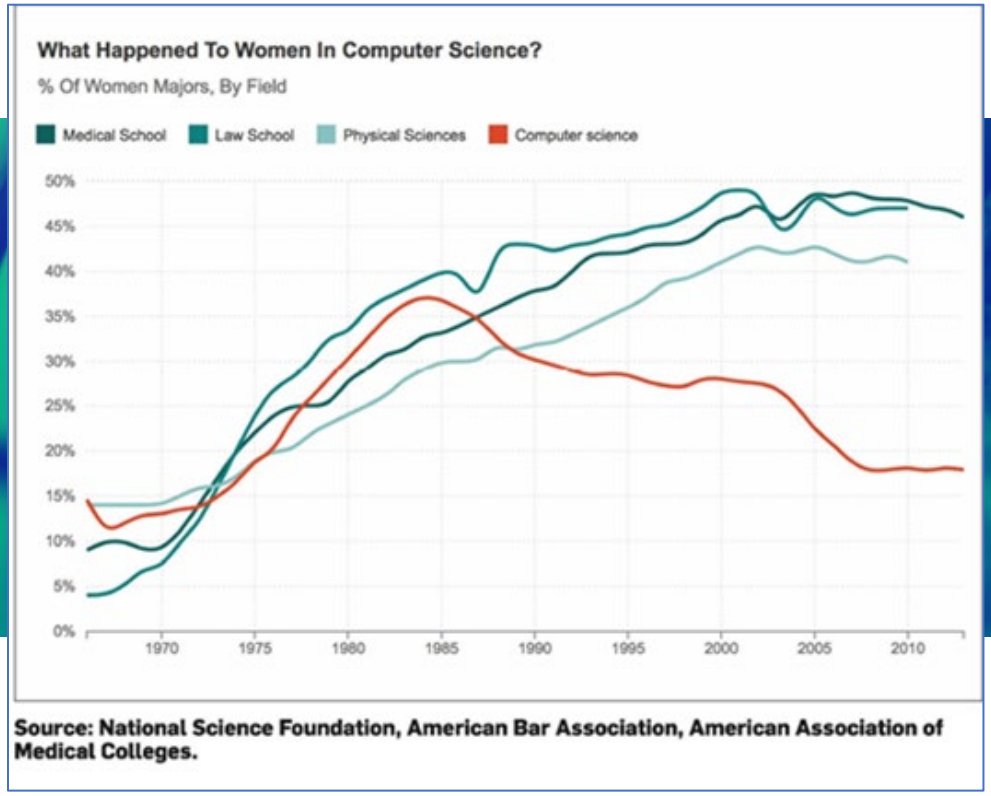
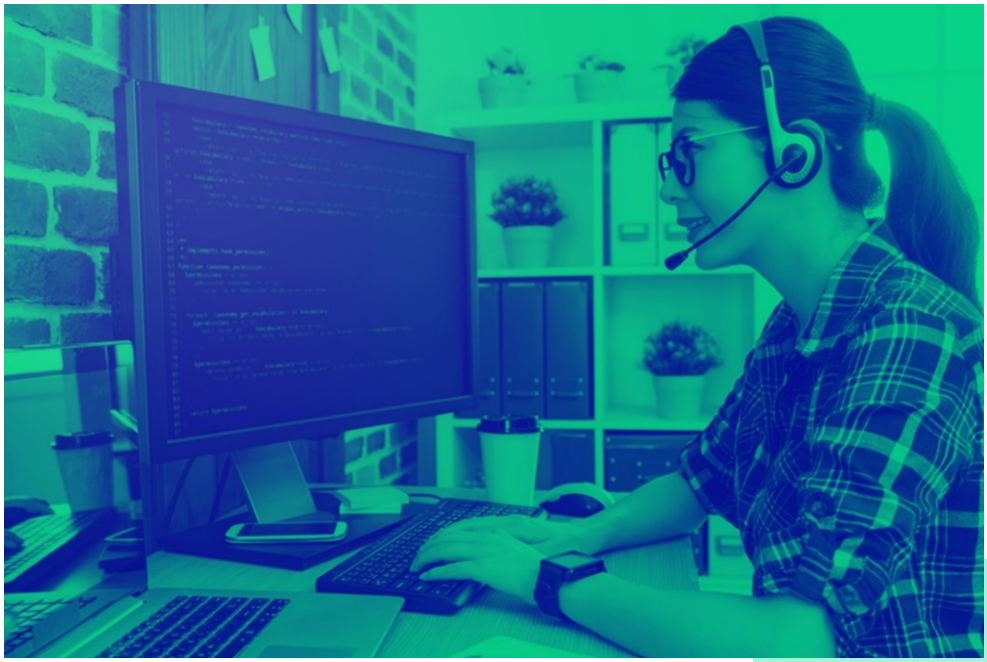


Image from Esther Shein (2018) *Broadening the Path for Women in STEM: Organizations work to address 'a notable absence of women in the field*. Communications of the ACM: pg. 19.

Women's underrepresentation in computing is pronounced among Whites, and even more pronounced among African Americans and Hispanics.[7] Today's high school students can change that. High school students' voices foreshadow the future. Their aspirations are a bellwether of the computing talent pool that will be available to fill the growing number of positions. Listening to their voices can inform effective evidence-based interventions for today to expand the computing workforce of tomorrow.

This report analyzes data from a 2018-19 survey conducted in-class, nationwide by the Student Research Foundation. (See Appendix A for details.) Analyzing these data, we:

- Assess the need for interventions to narrow the gender gap in computing aspirations.
- Identify insights about females in the potential computing talent pool.
- Offer ideas to attract and retain high school girls interested in computing.



Gender Gap Forecast

The survey finds approximately one in ten students (9.7%) aspire to Computing Careers.[8] However, male computing aspirants outnumber females 4:1 [Figure 1].

Moreover, these female computing aspirants may be more vulnerable to abandoning STEM. They are more likely than their male counterparts to be considering simultaneously STEM and non-STEM careers[9] [Figure 2].

These gender differences hold among racial/ethnic groups historically overrepresented (ORGs) and historically underrepresented (URGs) in STEM.[10]

Figure 1: Males Aspiring to Computing Careers Outnumber Females 4:1

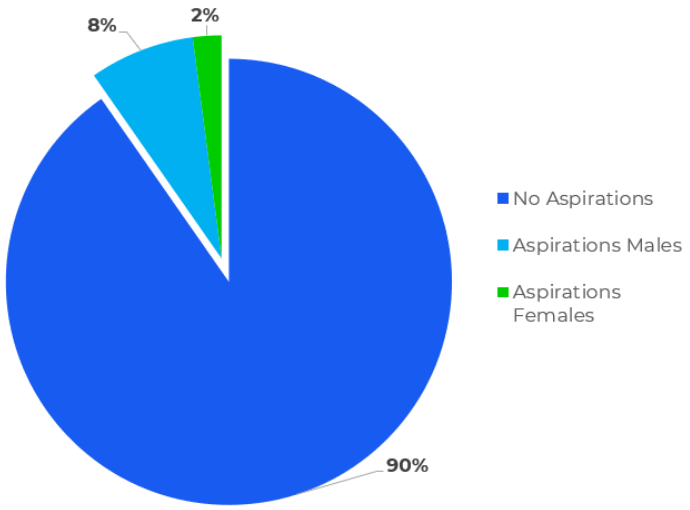
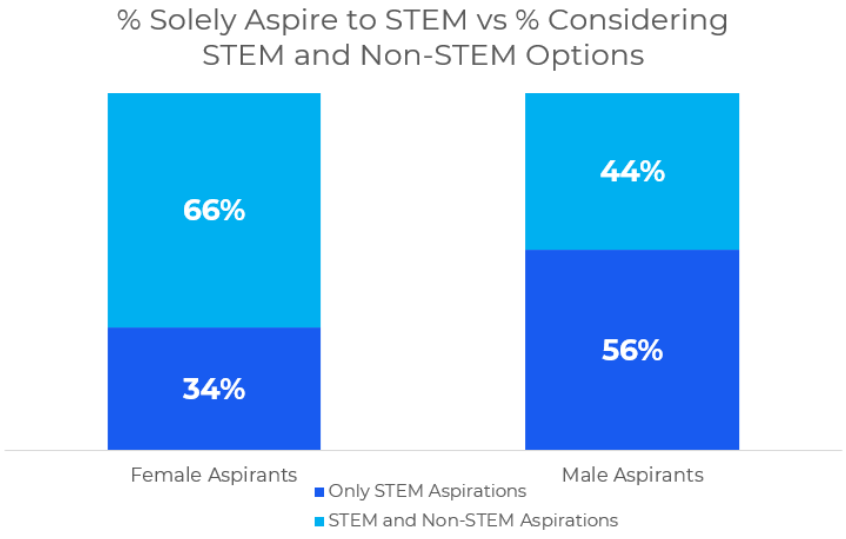


Figure 2: Among Computing Aspirants, Girls Are More Likely to be Torn Between STEM and Non-STEM Options



Insights to Inform Effective Interventions

Insight 1: STEM Confidence is an Exceptional Challenge for Girls Interested in Computing[11]

Research repeatedly shows males and females are equally qualified to pursue STEM pathways.[12] Indeed, SRF's data confirm that. The Fall 2018 survey finds female computing aspirants are more likely than male aspirants to be "A" students (54% vs. 41%).[13] Nevertheless, male computing aspirants more often score high on STEM confidence.

Students rated their STEM confidence on four statements. These spanned understanding of (basic and difficult) STEM concepts to expectations of (educational and career) success in STEM. Yet despite girls' more impressive GPAs, STEM confidence is *an exceptional problem for female computing aspirants* [Figure 3]. Female computing aspirants are:

- less likely to be "completely" confident of their STEM abilities than male aspirants.[14]
- less likely to be "completely" confident of their STEM abilities *than females who aspire to non-computing STEM careers*.[15]
- similar in STEM confidence to females with no STEM career aspirations.[16]

Overall, only among computing aspirants do females score lower than their male counterparts on all four measures of STEM confidence [Figure 3a].

Figure 3: Female Computing Aspirants Are Less Confident on Four Measures of STEM Confidence

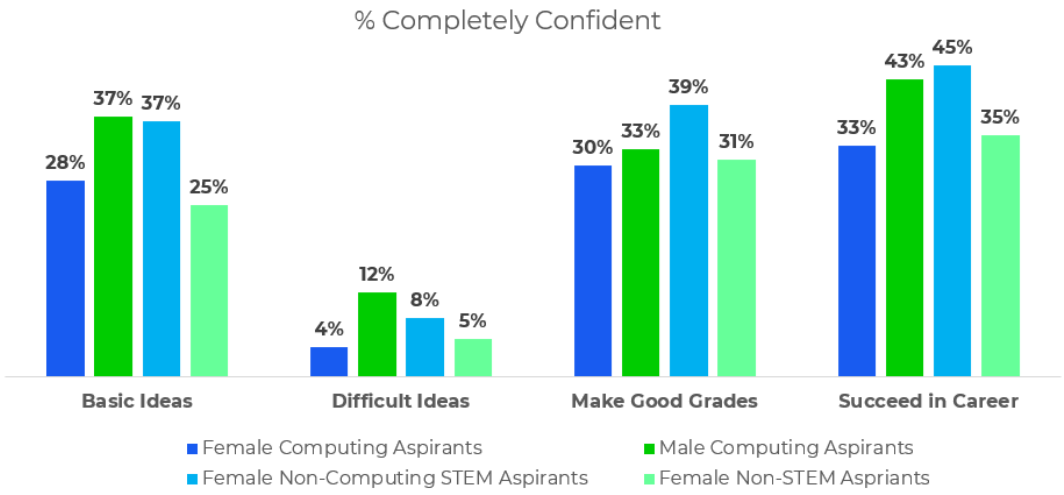
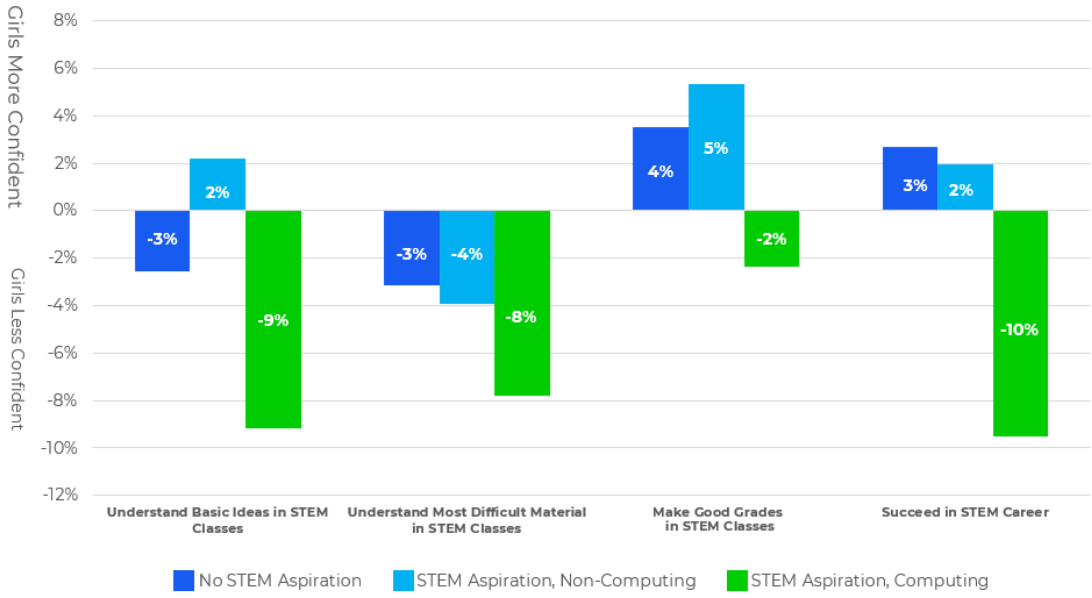


Figure 3a: Gender Gap in STEM Confidence



Research shows STEM confidence matters.[17] Those with low STEM confidence are less likely to aspire to computer science.[18] Students with high STEM confidence are more likely to persist in math and science.[19] High STEM confidence may be a protective factor that insulates students from the negative impact of the inevitable challenges they will encounter in achieving their goals.[20]

Without effective intervention, the already small minority of high school girls in this cohort who are interested in computing could dwindle further as they progress toward college and career.[21]

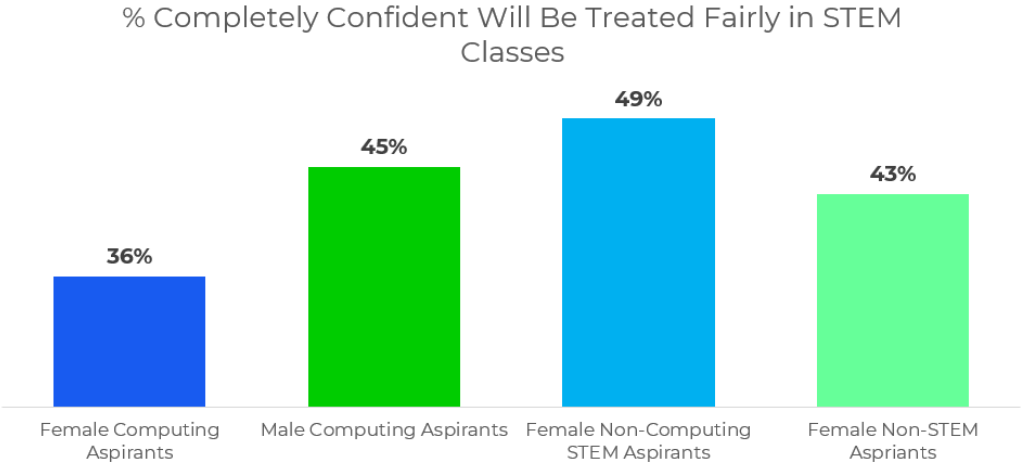
Insight 2: Female Computing Aspirants are Least Confident of Fair Treatment in STEM Classes[22]

Female computing aspirants are less likely to expect they will be treated fairly in STEM classes than:

- *males* aspiring to computer careers.
- *females* aspiring to non-computing STEM careers.
- *females* with no STEM aspirations.[23] [Figure 4]

This is consistent with work that suggests boosting girls' sense of belonging is critical to persistence in computing.[24] Micro-messaging that signals to females they do not fit discourages them from pursuing or persisting in computing. These messages can range from seemingly trendy décor that makes more boys than girls feel welcomed, to subtle and not-so-subtle slights in the classroom. The lower expectation of fairness in the classroom could be related to a variety of factors – from interactions with peers or teachers, to gender imbalance in computing classes. The dynamics driving this pattern merit further investigation in future work.

Figure 4: Female Computing Aspirants Are Least Likely to be Completely Confident of Fair Treatment in STEM Classes



Insight 3: "What Matters" to Girls and Boys Differs Dramatically. That Affects Diversity.

While boys have long been attracted to computing by the mechanics of programing, diversity advocates believe that has far less appeal to girls. Instead, they assert, showing girls computing can help them accomplish *what matters to them* is key to attracting girls to computing careers.[25]

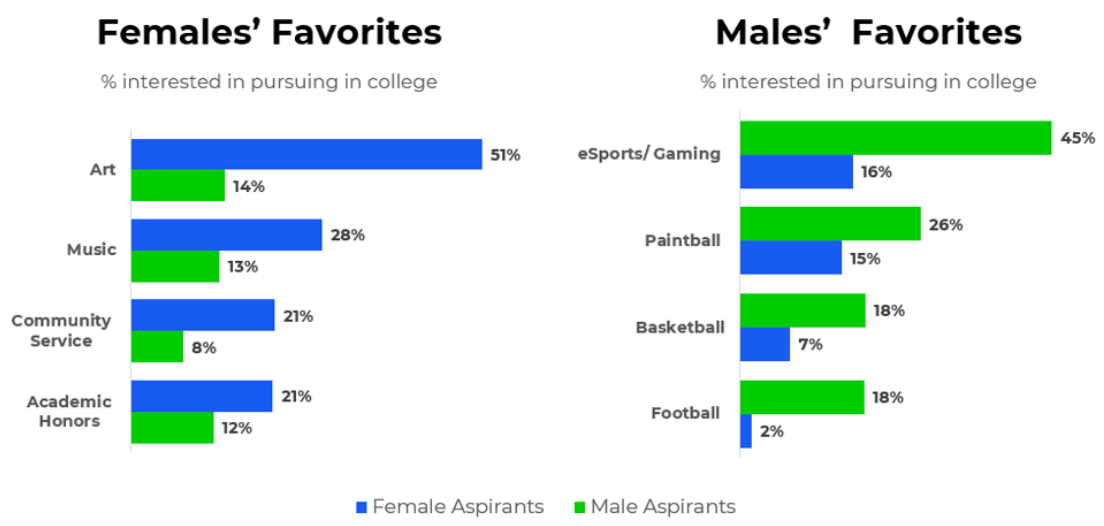
Extracurricular activity preferences are one indicator of "what matters" to students. The Fall 2018 SRF survey asked students to choose from a list of 50 extracurricular activities the ones they planned to pursue in college.

The data show sharp gender differences in the extracurricular interests of students aspiring to the computing field [Figure 5]. Among computing aspirants,

- nearly half of male students plan to pursue eSports, while half of females plan to pursue art.[26]
- males' favorites have limited appeal to females; females' favorites have limited appeal to males.[27]

One-size-fits-all approaches seem unlikely to fit – if the goal is gender balance in the computing field. Retaining female computing aspirants (and attracting more girls to computing) likely means offering students choices and steering clear of curricula and examples that consistently appeal to one segment of students. One size does not fit all.

Figure 5: Computing Aspirants' Favorite College Extracurricular Activities



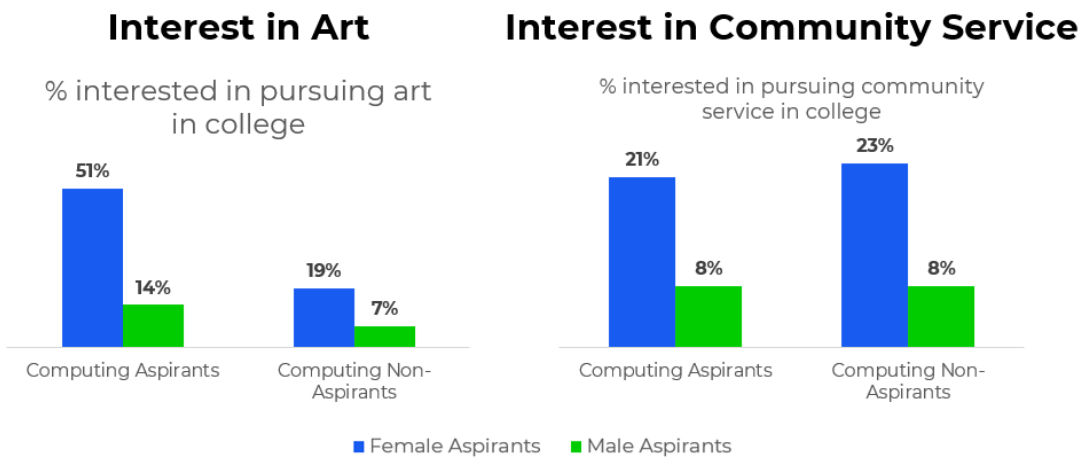
Such strategies will be particularly productive in promoting diversity if "what matters" to female computing aspirants also matters to sizeable segments of female *non-computing*

aspirants who could be attracted to the field. We assess the recruitment potential by comparing the level of interest in the top extracurricular activities among the 4% of girls who express an interest in computing careers with the level of interest in them among the 96% of girls with no current interest in computing.

Figure 6 shows that two interests once thought to depress girls' interest in computer science careers – art and community service[28] – have great potential to attract girls who have not considered computing. However, only art's potential seems to have been realized.

- Art is relatively more popular among male and female computing aspirants than among non-aspirants.
- Community service has similar appeal to students whether they aspire to computing or not.

Figure 6: Art and Community Service Have Potential to Attract More Girls to Computing



With about one in five female computing non-aspirants hoping to pursue these activities in college, explicitly demonstrating that computing can be a tool not only for pursuit of art[29] but also community service/ social justice[30] seems likely to further broaden the path to computing careers. That can advance gender diversity.[31]

Insight 4: Adults are positive influences on STEM interest *more often for females considering non-computing STEM careers* than for females considering computing careers. [32]

Validation from caring adults is especially important for attracting girls to the STEM pipeline and retaining them.[33] Validation sends the message "You fit" and "You can succeed."[34] Moreover, adults can also provide critical social and cultural capital to help students convert computing interest into career success.

Students rated the impact of teachers, parents, and other adults on their STEM interest. Three patterns are particularly relevant.

- Female computing career aspirants are slightly *more likely* than males to rate adults as positive influences on STEM interest [Figure 7].[35] This was somewhat surprising given the gender gap in STEM confidence and females' lower expectations of fairness.
- However, female computing aspirants *are* disadvantaged compared to females who aspire to other STEM careers [Figure 8]. Computing aspirants are *less likely* to rate each type of adult – parents, teachers, and other adults – as having a positive influence on their STEM interest.
- Generally, teachers are more likely to be mentioned as positive influences on STEM interest than parents or other adults are. This poses a unique challenge for girls interested in computing (given the scarcity of classes), and it makes a compelling case that universal access to computer science classes are needed to promote diversity.

Figure 7: Female Computing Aspirants Are Slightly More Likely Than Male Aspirants to Report Adults As Positive Influences on STEM Interest

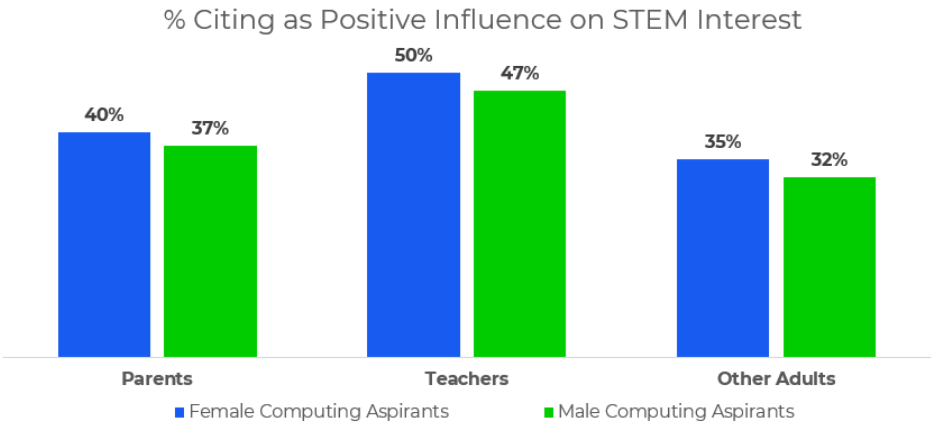
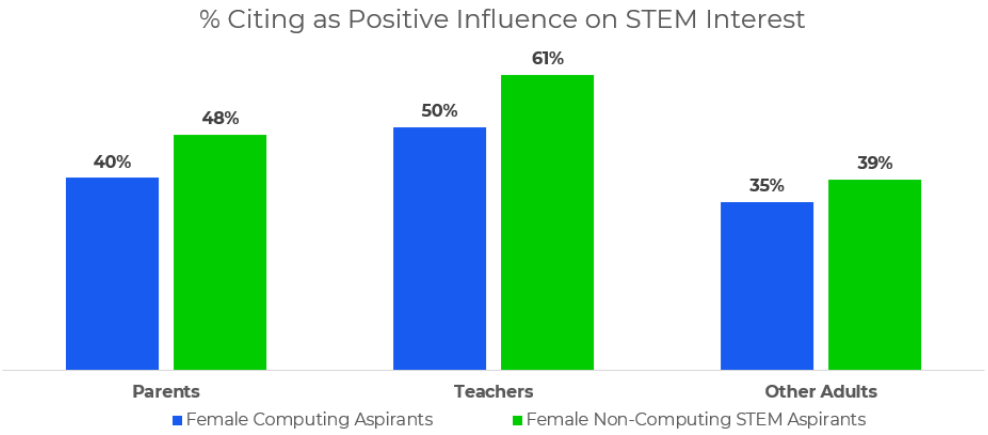


Figure 8: Adults Are More Likely Positive Influences on STEM Interest among Girls with Non-Computing than Computing STEM Aspirations



Insight 5: The lower level of adult influence on STEM interest among girls who aspire to computing is concentrated among computing career aspirants interested in art.[36]

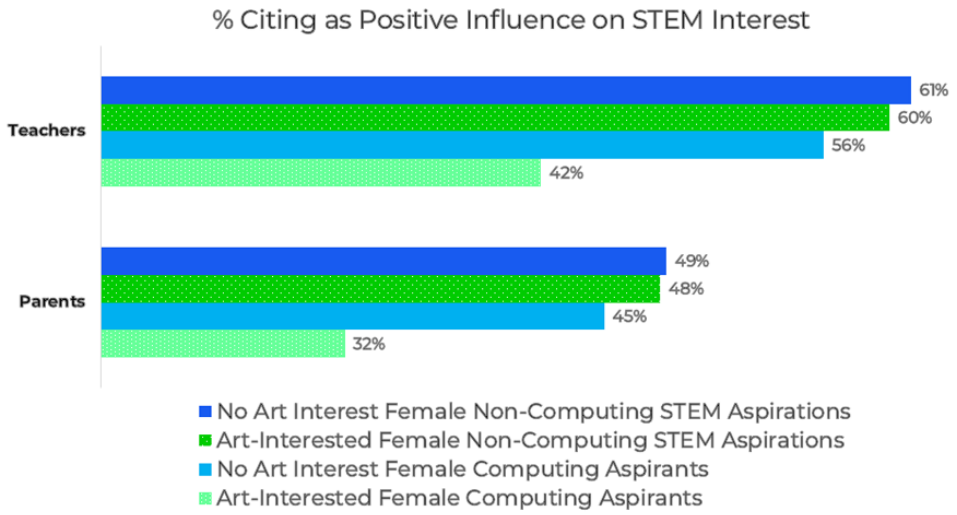
The last section showed that among female STEM aspirants, girls who aspire to computing careers are less likely than other girls to say adults – particularly parents and teachers – have been positive influences on their interest in STEM.

This section takes that analysis one step further. Given that half of female computing career aspirants seem to value art – that it is "what matters" to them, this section compares the influence of parents and teachers on STEM interest when type of STEM career aspiration (computing vs. non-computing) intersects with interest in art.

Figure 9 suggests *intersectionality* of interests is critical to understanding the gap in adult support between female computing aspirants and other female STEM career aspirants. The lower ratings of teachers and parents as a positive influence is concentrated among *female computing aspirants interested in art*. Among girls who aspire to STEM careers:

- Interest in art, alone, does *not* depress the influence of adults on girls' STEM interest. Females interested in art and aspiring to non-computing STEM fields are substantially *more* likely to rate teachers and parents as positive influences than are their counterparts who aspire to computing.
- Interest in computing, alone, does not depress the influence of adults on girls' STEM interest. Females aspiring to computing, but with no interest in art, rate teachers and parents as positive influences almost as often as those females who aspire to non-computing STEM fields and have no interest in art.

Figure 9: Art-Interested Girls with Computing Aspirations Cite Adults as Positive Influences Less Often than Other Girls with STEM Aspirations



The data do not allow us to identify the reasons for the disparities – yet the patterns once again suggest one size will not fit all.[37] For those who believe adult support can be a valuable resource to even the most intrepid self-starters, these results raise an important question: If art is broadening the path to careers in computing, why are girls who may have taken this path less inclined to view adults as a positive influence on their STEM interest?

Insight 6: Informal pastimes are equally valued across the subgroups of students aspiring to STEM careers. However, female computing aspirants are less likely than other STEM aspirants to value formal activities.[38]

Females who aspire to STEM careers – whether in computing or not – and males who aspire to computing are equally likely to rate informal pastimes[39] as positive influences on their STEM interest [Figures 11, 12]. This pattern is consistent with previous research suggesting self-directed pastimes are powerful forces for attracting young people to STEM and retaining them.[40]

The similarity across the three groups of STEM aspirants diminishes, however, when they rate more formal STEM activities. Female computing career aspirants are:

- *less likely* than male computing aspirants to rate out-of-school activities as positive influences on their STEM interest [Figure 10]. (They rate the impact of school activities similarly.)
- *less likely* than females who aspire to non-computing STEM careers to rate school activities as positive influences on their STEM interest [Figure 11]. (They rate the impact of out-of-school activities similarly.)

The next section examines the gap among female STEM aspirants' ratings of school activities, reaffirming the diversity even among girls interested in computing.

Figure 10: Few Gender Differences in Positive Influences in STEM Interest among Computing Aspirants

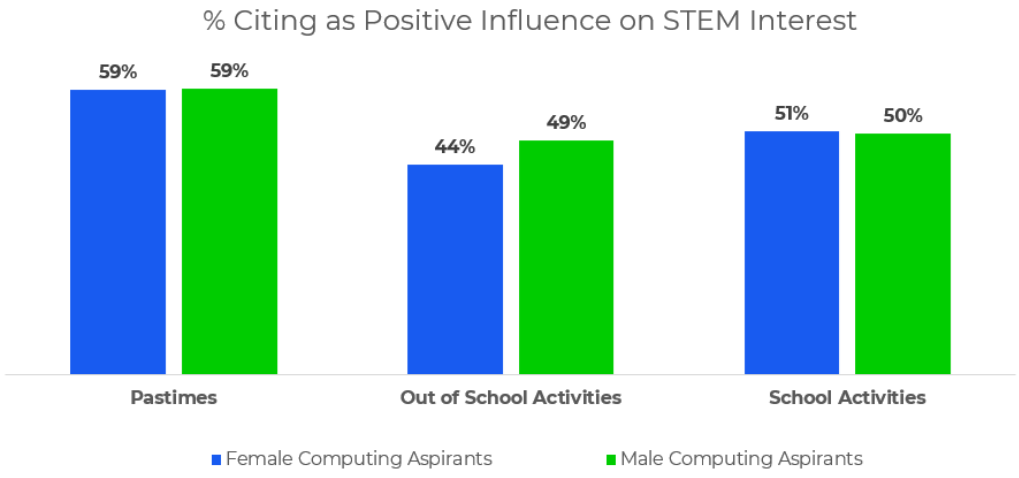
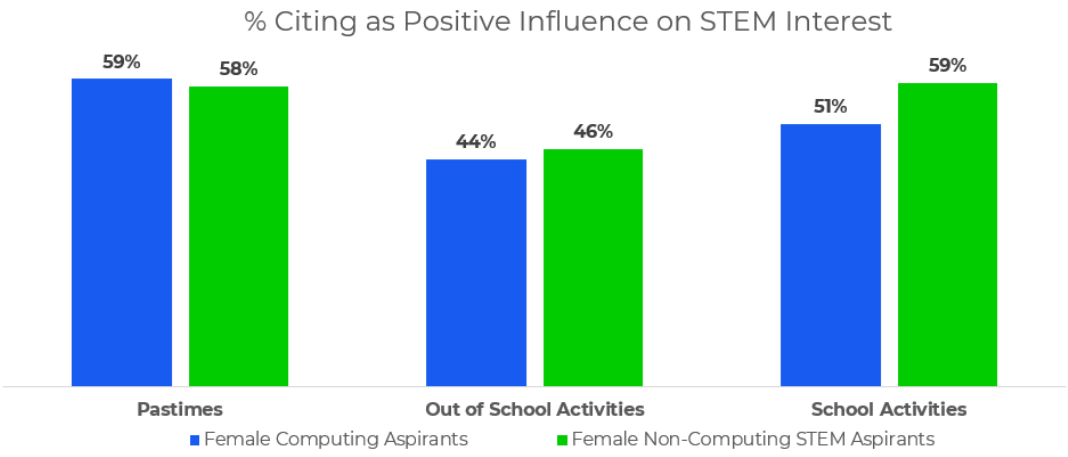


Figure 11: Activities Vary in Relative Importance as Positive Influences on STEM Interest among Female STEM Aspirants



Insight 7: Girls who combine computing career aspirations with interest in art are less likely than other girls who aspire to STEM careers to rate school activities as a positive influence on STEM interest.

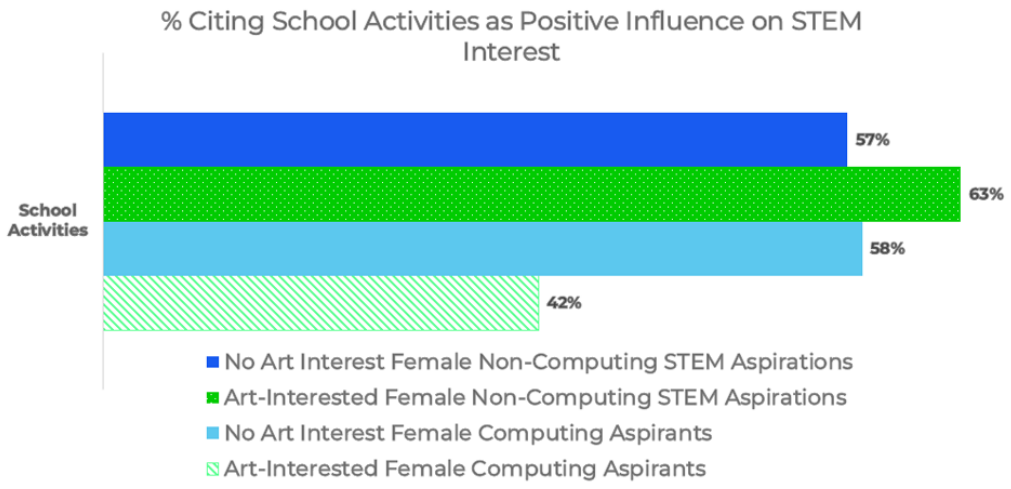
The previous section showed girls who aspire to computing are less likely than girls who aspire to non-computing STEM fields to rate school activities as positive influences on STEM interest. But the gap between the ratings of girls aspiring to computing and girls aspiring to non-computing STEM fields is driven largely by computing career aspirants who are interested in art.

The data show, once again, intersectionality of interests is important:

- Interest in computing, alone, does *not* depress the positive benefits of school activities. The lower ratings of school activities are concentrated among computing career aspirants with an interest in art. Female computing aspirants with no interest in art benefit from school activities at levels similar to females who aspire to non-computing STEM fields. [Figure 12]
- Interest in art, alone, does not depress the positive influence of school activities on STEM interest. Females interested in art and aspiring to non-computing STEM fields are substantially *more* likely to rate school activities as a positive influence on STEM interest than are their counterparts who aspire to computing and express an interest in art. [Figure 12]

While the growing importance of digital technology may be attracting more girls with a passion for art to computing, a broader path to computing careers is no guarantee their high school interest in computing will persist through college and into the professional world. Is it possible that as girls encounter ways that the digital world can apply to what matters to them, their less conventional path leaves them vulnerable to being left to their own devices to chart a career pathway?

Figure 12: Among Girls with STEM Aspirations, Art-Interested Girls with Computing Aspirations Benefit Relatively Less from School Activities



Insight 8: Girls who combine an interest in art with a computing career aspiration are less likely to know what their next step will be after high school graduation.

By 2020, 94% of STEM jobs will require training beyond a high school degree.[41] Knowing where to go after high school is important if a computing career is the goal. With so few female high school students aspiring to computing careers, it is especially important that girls interested in the field have a clear sense of their next steps after high school graduation.

With high school guidance counselors stretched thin,[42] providing guidance that promotes seamless progression from high school to career for every student may be challenging.

But more support seems likely to be particularly important for one segment – girls who may have been attracted to computing through its application to art. While they are as likely as other STEM aspirants to rate pastimes as a positive influence on their STEM interest, they are less likely to rate teachers, parents, school activities, and (to a lesser extent) out-of-school activities as positive influences. Whether they are just more self-directed than other girls with STEM career aspirations or being left to their own devices is unclear. However, if their independence from traditional influences on STEM interests leaves them more vulnerable as they transition from high school to postsecondary, that is a problem. This concern is even more valid given female computing career aspirants' lower levels of STEM confidence and lower expectations of fair treatment in STEM classes.

The data suggest girls who aspire to computing careers are more vulnerable than girls who aspire to other STEM fields because they are more likely to be uncertain of their postsecondary educational plans [Figure 13]. This holds across racial/ ethnic groups.[43]

But those who seem likely to have developed an interest in a computing career through a passion for art are the most vulnerable to being lost as they transition from high school [Figure 14]. The data show that *among females aspiring to STEM careers*:

- Educational uncertainty is ***least*** common among those aspiring to non-computing STEM fields (12%).
- Educational uncertainty is ***most*** common (26%) when computing career aspirations intersect with interest in art.

Figure 13: Among Females Aspiring to STEM Careers, Computing Aspirants Are More Likely to Be Uncertain of Postsecondary Education Plans

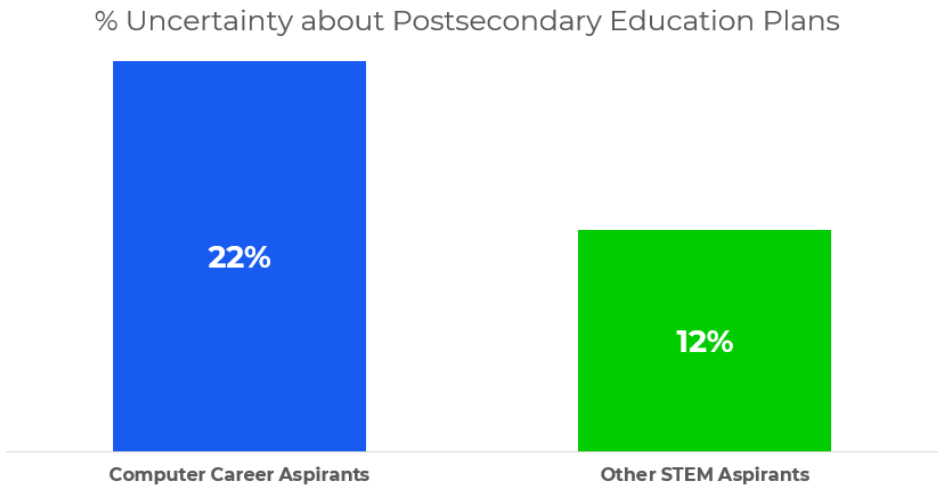
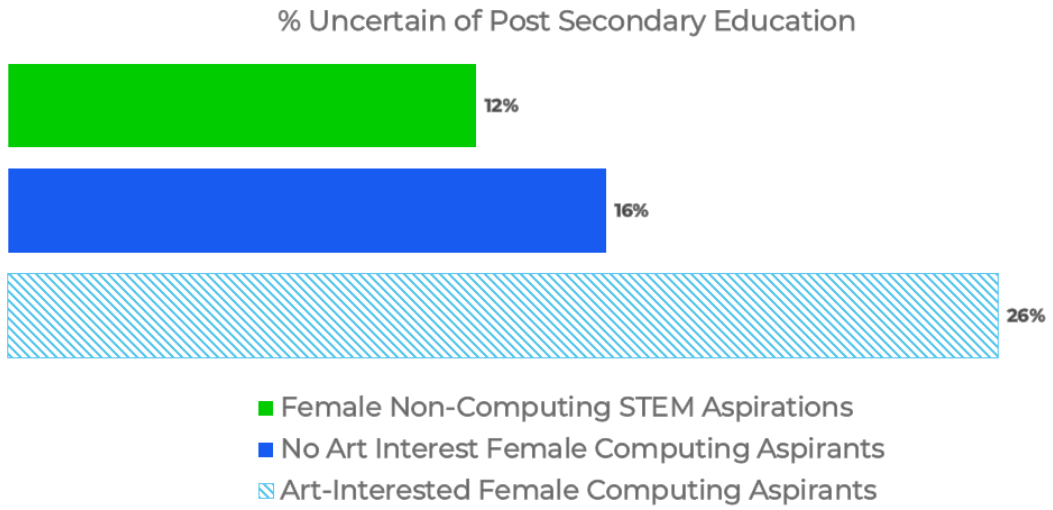


Figure 14: Among Girls with STEM Aspirations, Computing Sector Aspirations and Interest in Art Are Associated with Greater Uncertainty about Postsecondary Education Plans



If girls interested in art and computing are charting their own career pathway, their uncertainty about postsecondary education is a warning. Without increased investment in supports to guide them through the transition from high school to postsecondary, too many may be lost to non-STEM careers. [44]

CONCLUSION: CALL TO ACTION

The voices of students confirm that the gender gap in computing fields will likely continue as Gen Z moves into the workforce – unless effective interventions are implemented.

Listening to the voices of Gen Z's students provides insights on ways to empower them to rekindle the movement toward gender equity in computing lost with the Baby Boomer generation. The good news is many of the hints they provide are already being implemented. The challenge is bringing them to scale across the nation to allow the computing sector to flourish, to narrow the gender gap in pay, and to advance social justice.

Everyone has a role – titans of business, taxpayers, policymakers, parents, caring adults, non-profits, educators, and even students themselves. Part of the challenge is shattering deeply ingrained myths.

- Myth 1: Recognizing gendered interests is bad.

  Gendered interests exist. Doubters need only look at the preferred extracurricular activities of students in this study or the gendered occupational segregation in the U.S. workforce. "Gender-neutral" curricula and classrooms may unintentionally favor one gender. This is a particular challenge for computing.[45] Ensuring the assortment of educational activities aimed at serving all students actually appeal to all is important for narrowing the gender gap in computing. And allowing students, in the process, to rebel against gender stereotypes is equally important so that all fit.

- Myth 2: Equal = Equity.

  Just because male and female students are treated equally, does not ensure equity is achieved. Different students may have different needs. Girls may need more affirmation than boys to achieve equal levels of confidence for equal levels of achievement.[46] Coming to terms with the need for inequality to achieve equity goals – as well as the fairness of such behavior – will be important in order to narrow the gender gap in STEM generally and computing specifically.

- Myth 3: Computing class can wait until college.

  Students who never took a computing class in high school *can* take up computing in college. But those who wait may be at a disadvantage. Research suggests students benefit from early exposure to computing.[47] Colleges sometimes use introductory courses as weed-out classes, leaving the novice at a decided disadvantage.[48] The gender gap in STEM confidence puts girls at a decided disadvantage anyway, but especially when pitted against more knowledgeable peers.[49] With computing less available in high school to students from groups underrepresented in STEM,[50] this may doubly disadvantage Latinas and African American girls. But the uninitiated may never even think to take these classes. Indeed, computing career aspirants are less sure of their postsecondary educational path than other girls who aspire to STEM careers.

The other part of the equation is giving educators what they need.

- Educators need resources. Many high schools do not yet offer even one computer class.[51] The arts are often the first victims of budget cuts. Policymakers need to re-think priorities.

- Educators need time. School days are short. Out-of-school time activities are often more accessible to the privileged.

- Educators need partners. Disciplinary boundaries are strong. STEAM education is oft-discussed, but poses challenges to both the computer science and arts disciplines.[52] Connecting computer science with community service may sometimes spur political debates.[53] But successful partnerships may help expand the talent pool so the U.S. computing sector has the human resources to grow and talent to innovate.

Advances in digital technology over the past decade has opened new opportunities to attract more girls to the computing field through their passion for art. The data presented here suggest even more girls could be attracted to computing through art. The question that these data raise, however, is whether that interest can persist beyond high school, and perhaps lead girls to a much broader array of applications than they would have ever considered.

Appendix: Research Methods

This report analyzes data from a 2018-19 survey conducted in-class, nationwide by the Student Research Foundation. 74,149 high school students completed surveys.[54] One version of the survey, distributed to high school STEM teachers, was completed by 18,681 students.

When possible, the analysis is based on responses from the full sample. Some sections of the analysis, however, rely on questions that appear on solely the version of the survey distributed to students by STEM teachers. These sections are noted.

To ensure the results based on the full sample were replicated among the sample of students in STEM classes, we replicated them. The tests confirmed the patterns were consistent across the two samples – although there were minor differences in percentages. The differences between the STEM subset and the full sample are likely minimal because many of those in STEM classes are filling requirements, building resumes for college admissions, and hoping to earn AP credits to meet college distribution requirements.

[1] https://www.bls.gov/ooh/computer-and-information-technology/home.htm
[2] https://smallbiztrends.com/2018/03/women-in-technology-statistics.html; also see https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html; Esther Shein (2018) *Broadening the Path for Women in STEM: Organizations work to address 'a notable absence of women in the field*. Communications of the ACM. http://delivery.acm.org/10.1145/3240000/3231170/p19-shein.pdf?ip=40.77.167.189&id=3231170&acc=OPEN&key=C2BAB59091A35C3F%2EC2BAB59091A35C3F%2E4D4702B0C3E38B35%2E6D218144511F3437&__acm__=1559467784_4e7c0e3720c5ce99bd845dc87b3d2b66
[3] https://www.bls.gov/cps/cpsaat11.htm. Last Modified Date: January 18, 2019. Note BLS defines the referenced category as computer and mathematical occupations.
[4] SOURCE: Women and Information Technology by the Numbers. U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Fall 2016 and Fall 2017, Completions component. Table prepared August 2018.
[5] Esther Shein (2018) *Broadening the Path for Women in STEM: Organizations work to address 'a notable absence of women in the field*. Communications of the ACM.
[6] Image from Esther Shein (2018) Broadening the Path for Women in STEM: Organizations work to address 'a notable absence of women in the field. Communications of the ACM: pg. 19. For more information see https://images.app.goo.gl/yxeAQixTVC2SGYYW8.
[7] Based on women's presence in the labor force overall, White women hold only 47% of the computing jobs they should, African American women hold only 37% of the computing jobs they should, and Hispanic women hold merely 24% of the jobs they should.
[8] Computing careers are defined as the following options presented in one or more surveys distributed to high school students: Animation, App Mobile Tech, Coding, Computer Science, Cyber Security, Data Science Business Analytics, Game Design, Internet Ecommerce Tech, Web Design, Computer Info Sci Engineering, IT, Coding Programming, Computer Info Systems, Computer Network Engineering, Computer Network Mgt Admin, Computer Network Tech, Computer Office Tech, Computer Repair, Computer Science, Computer Technician, Computer Technology, Electronics Computer Tech, Game Software Development, Internet Information System, Network System Support, Network Tech.
[9] An alternative explanation is that those who choose two different careers are interested in combining the two – not choosing between them. The data do not allow empirical testing of the two possible reasons for aspirations in two different sectors.
[10] Similarly, the overall pattern of gender differences among those torn between computing and non-STEM careers holds among ORGs (63% vs. 40%) and URGs (67% vs. 47%).
[11] The findings in this section were administered to a subset of students in STEM classes in Fall 2018. Data are from the Student Career Interest Survey sponsored by the Research Consortium on STEM Career Pathways (N=18,681).
[12] E. Tiffany Iskander, Paul A. Gore Jr., Cynthia Furse, and Amy Bergerson. 2013 "Gender Differences in Expressed Interests in Engineering-Related Fields ACT 30-Year Data Analysis Identified Trends and Suggested Avenues to Reverse Trends." Journal of Career Assessment 21(4) 599-613. DOI: 10.1177/1069072712475290
[13] Among ORGs, "A" students are 62% of female aspirants and 48% of male aspirants. The comparable percentages for URGs are 48% and 35%.
[14] See Linda J. Sax, Kathleen J. Lehman, Jerry A. Jacobs, M. Allison Kanny, Gloria Lim, Laura Monje-Paulson & Hilary B. Zimmerman (2017) Anatomy of an Enduring Gender Gap: The Evolution of Women's Participation in Computer Science, The Journal of Higher Education, 88:2, 258-293, DOI: 10.1080/00221546.2016.1257306. Also see Sax, L. J., Kanny, M. A., Riggers-Piehl, T. A., Whang, H., & Paulson, L. (2015). 'But I'm not good at math': The changing salience of mathematical self-concept in shaping women's and men's STEM aspirations. Research in Higher Education, 56, 813–842. doi:10.1007/s11162-015-9375-x.
[15] This holds even though female STEM aspirants who aspire to non-computing sectors are only somewhat more likely to report they are "A" students than female computing aspirants are (58% vs. 54%) and are actually more likely to be torn between STEM and non-STEM careers (79% vs. 66%).
[16] This is consistent with a recent study of computer science majors. See Kathleen J. Lehman, Linda J. Sax, and Hilary B. Zimmerman. 2016. "Women planning to major in computer science: Who are they and what makes them unique?" Computer Science Education 26:4, pg. 277-298. https://doi.org/10.1080/08993408.2016.1271536.
[17] https://www.theatlantic.com/magazine/archive/2014/05/the-confidence-gap/359815/
[18] Linda J. Sax, Kathleen J. Lehman, Jerry A. Jacobs, M. Allison Kanny, Gloria Lim, Laura Monje-Paulson & Hilary B. Zimmerman (2017) Anatomy of an Enduring Gender Gap: The Evolution of Women's Participation in Computer Science, The Journal of Higher Education,

88:2, 258-293, DOI: 10.1080/00221546.2016.1257306

[19] For review of the literature see Lori Andersen and Thomas J. Ward (2014) "Expectancy-Value Models for the STEM Persistence Plans of Ninth-Grade, High-Ability Students: A Comparison Between Black, Hispanic, and White Students," Science Education, Vol. 98, No. 2, pp. 216–242. Also see Jessica J. Gottlieb (2018) "STEM career aspirations in Black, Hispanic, and White ninth-grade students." J Res Sci Teach. 55:1365-1392; Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. Child Development, 72: 187 – 206; Eccles, J. S. (2005). Studying gender and ethnic differences in participation in math, physical science, and information technology. New Directions for Child and Adolescent Development, (110), 7 – 14; Simpkins, S. D., Davis-Kean, P. E., and Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. Developmental Psychology, 42, 70 – 83; Mau, W. C. (2003). Factors that influence persistence in science and engineering career aspirations. Career Development Quarterly, 51, 234 – 243.

[20] Because Hispanics and ORGs in STEM classrooms aspire to STEM careers at similar rates, the role of confidence as a protective factor seems more appropriate. See Ming-Te Wang, Feifei Ye, and Jessica Lauren Degol. (2017) "Who Chooses STEM Careers? Using A Relative Cognitive Strength and Interest Model to Predict Careers in Science, Technology, Engineering, and Mathematics." Journal of Youth Adolescence. 46:1805-1820.

[21] Students self-reported their overall GPA. "A" students were more common among female than male computing aspirants (54% vs. 41%). While they were slightly more common among females aspiring to non-computing STEM fields than computing (58% vs. 54%), female computing aspirants were slightly more likely than females with no STEM aspirations to self-report as "A" students (54% vs. 51%).

[22] The findings in this section were administered to a subset of students in STEM classes in Fall 2018. Data are from the Student Career Interest Survey sponsored by the Research Consortium on STEM Career Pathways (N=18,681).

[23] The differences in GPA cannot account for differences. [44]

[24] W. DuBow, A. Kaminsky and J. Weidler-Lewis, "Multiple Factors Converge to Influence Women's Persistence in Computing: A Qualitative Analysis" in Computing in Science & Engineering, vol. 19, no. 03, pp. 30-39, 2017. doi: 10.1109/MCSE.2017.42; Wendy M. DuBow, Ruthe Farmer, Zhen Wu, and Malia Fredrickson. (2013) "Broadening Participation: Bringing Young Women into Computing Through the NCWIT Aspirations in Computing Program." Communications of the acm. (December 2013) 56:12. Pg. 34-37. doi:10.1145/2535917.

[25] Yu, Andrea. "The benefits of encouraging STEM to young girls." Maclean's, Apr. 2017, p. 63.

[26] The gender divide in favorite interests generally holds among ORGs and URGs. The one exception is "academic honors." It is ranked third among ORG males and females, making it the only interest that is shared among the top choices.

[27] Male aspirants' most popular extracurricular, eSports, is a favored extracurricular of almost half of male computing aspirants – but of far fewer girls aspiring to computing careers. Similarly, more than half of female computing aspirants want to pursue art as an extracurricular pursuit in college – while far fewer male computing aspirants do.

[28] See Linda J. Sax, Kathleen J. Lehman, Jerry A. Jacobs, M. Allison Kanny, Gloria Lim, Laura Monje-Paulson & Hilary B. Zimmerman (2017) Anatomy of an Enduring Gender Gap: The Evolution of Women's Participation in Computer Science, The Journal of Higher Education, 88:2, 258-293, DOI: 10.1080/00221546.2016.1257306

[29] https://spectrum.ieee.org/view-from-the-valley/at-work/education/want-girls-attracted-to-tech-put-a-for-art-in-stem

[30] For sampling of books on AI and ethics see https://fivebooks.com/best-books/ethics-artificial-intelligence/

[31] In contrast, a narrow path – one focused on the status quo that relies on masculine interests – is unlikely to increase gender diversity in the computing sector. The favorite activity of male computing aspirants, eSports, has low potential to attract more females to the computing fields. With 3% of females aspiring to non-computing STEM fields and merely 1% aspiring to non-STEM fields, the growth potential of leaning in to the pastimes favored by males is likely to have little benefit in reaching more girls.

[32] The findings in this section were administered to a subset of students in STEM classes in Fall 2018. Data are from the Student Career Interest Survey sponsored by the Research Consortium on STEM Career Pathways (N=18,681).

[33] Jennifer Wang, Hai Hong, Jason Ravitz, and Marielena Ivory. "Gender Differences in Factors Influencing Pursuit of Computer Science and Related Fields." ITICSE '15, Jul 04-08, 2015, Vilnius, Lithuania. ACM 978-1-4503-3440-2/15/07. http://dx.doi.org/10.1145/2729094.2742611; also see Ashcraft, C., Eger, E., and Friend, M. Girls in IT: The Facts. National Center for Women & Information Technology, 2012; http://www.ncwit.org/thefactsgirls cited in Wendy M. DuBow, Ruthe Farmer, Zhen Wu, and Malia Fredrickson. (2013) "Broadening Participation: Bringing Young Women into Computing Through the NCWIT Aspirations in Computing Program." Communications of the acm. (December 2013) 56:12. Pg. 34-37. doi:10.1145/2535917.

[34] https://www.nytimes.com/2013/10/06/magazine/why-are-there-still-so-few-women-in-science.html
[35] This is despite they are less confident of fair treatment in STEM classes.
[36] The findings in this section were administered to a subset of students in STEM classes in Fall 2018. Data are from the Student Career Interest Survey sponsored by the Research Consortium on STEM Career Pathways (N=18,681).
[37] Although the focus of this report is on boosting the representation of girls in the computing labor force, it is noteworthy that males who share interests in art and computing mirror girls when it comes to the (low) positive impact of teachers and parents on their STEM interest.
[38] The findings in this section were administered to a subset of students in STEM classes in Fall 2018. Data are from the Student Career Interest Survey sponsored by the Research Consortium on STEM Career Pathways (N=18,681).
[39] "Pastimes" is shorthand for the heterogeneous category listed in the student survey, "TV, movies, books, social media, games or toys."
[40] McCreedy, D. & Dierking, L.D. (2013). Cascading influences: Long-term impacts of informal STEM experiences for girls. Philadelphia, PA: The Franklin Institute. Retrieved from http://www.informalscience.org/cascading-influences-long-term-impacts-stem-informalexperiences-girls. Also see Rong Su, James Rounds, and Patrick Ian Armstrong. "Men and things, women and people: A meta-analysis of sex differences in interests." Psychological Bulletin, Vol 135(6), Nov, 2009. pp. 859-884.
[41] https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.ES_.Web_.pdf
[42] https://www.npr.org/sections/ed/2018/02/26/587377711/with-hundreds-of-students-school-counselors-just-try-to-stay-afloat
[43] The pattern holds across racial groups as well. Among STEM aspirants from historically overrepresented groups (ORGs), 22% of computing aspirants are uncertain compared with 12% of non-computing STEM aspirants. Among those from groups historically underrepresented in STEM (URGs), 22% of computing aspirants are uncertain compared with 12% of non-computing STEM aspirants are uncertain of postsecondary educational plans. The pattern of greater uncertainty among computing aspirants persists when URG/ORG STEM aspirants are disaggregated: Asian females – 20% computing vs 6% non-computing, White females – 23% computing vs. 13% non-computing, African American females – 13% computing vs 8% non-computing, and Hispanic females – 22% computing vs 11% non-computing. The racial group breakdowns should be viewed with caution due to small Ns.
[44] Recent research suggests the high level of uncertainty among high school students continues as students matriculate to college. for among those intending to major in computer science, girls are more likely than boys to be uncertain of their career path. See Kathleen J. Lehman, Linda J. Sax, and Hilary B. Zimmerman. 2016. "Women planning to major in computer science: Who are they and what makes them unique?" Computer Science Education 26:4, pg. 277-298. https://doi.org/10.1080/08993408.2016.1271536.
[45] Elizabeth Patitsas, Michelle Craig and Steve Easterbrook. "A Historical Examination of the Social Factors Affecting Female Participation in Computing." ITICSE '14, June 21 - 25 2014, Uppsala, Sweden. http://dx.doi.org/10.1145/2591708.2591731. Also see https://www.nytimes.com/2019/02/13/magazine/women-coding-computer-programming.html
[46] https://www.parentmap.com/article/stream-girls-women-math-science
[47] Sapna Cheryan, Sianna A. Ziegler, Amanda K. Montoya, Lily Jiang. 2017 "Why Are Some STEM Fields More Gender Balanced Than Others?" Psychological Bulletin, Vol. 143, No. 1, 1–35. http://dx.doi.org/10.1037/bul0000052.
[48] Sax, L., Blaney, J. M., Lehman, K. J., Rodriguez, S., George, K., & Zavala, C. (2017). Sense of belonging in computer science: The role of introductory courses for women and underrepresented minority students. Proceedings of the 2017 Paper presented at the Study of Higher Education (ASHE) Conference. Houston, TX.
[49] Linda J. Sax, Kathleen J. Lehman, Christina Zavala. "Examining the Enrollment Growth: Non-CS Majors in CS1 Courses" SIGCSE'17, March 8–11, 2017, Seattle, WA, USA. DOI: http://dx.doi.org/10.1145/3017680.3017781
[50] https://code.org/files/2018_state_of_cs.pdf
[51] https://k12cs.org/wp-content/uploads/2016/09/K–12-Computer-Science-Framework.pdf
[52] James W. Bequette and Marjorie Bullitt Bequette. "A Place for ART and DESIGN Education in the STEM Conversation." Art Education, Vol. 65, No. 2 (March 2012), pp. 40-47
[53] http://neatoday.org/2018/12/11/political-neutrality-in-the-classroom-shortchanges-students/
[54] Some questions specific to STEM experiences were included only on the version of the survey sent to STEM teachers. 18,169 students completed this version of the survey. Sections based on responses to only one version of the survey are noted.