GIRLS IN IT: THE FACTS

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Dedication: In loving memory of Maya

Technology is EVERYWHERE, but **where are the girls?**

Girls comprise 56% of all Advanced Placement (AP) test-takers, 46% of all AP Calculus test-takers, **BUT ONLY** 19% of AP Computer Science test-takers.

GIRLS IN IT: THE FACTS

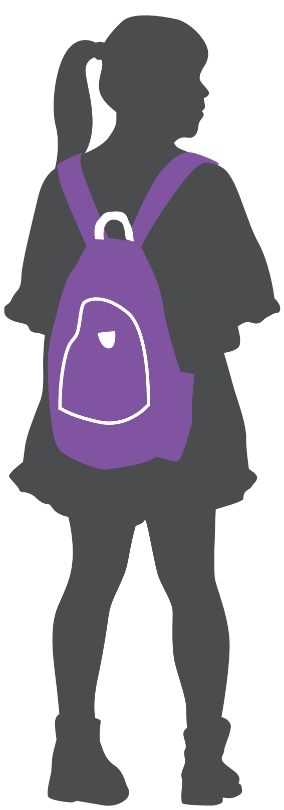
ABOUT THIS REPORT

Technology is everywhere, but **where are THE GIRLS?**

Information Technology (IT) increasingly permeates every aspect of society and provides the foundation for most modern innovation. Our girls are avid users of new technologies, but, to date, girls and women continue to be significantly underrepresented in technical occupations. This pattern is particularly troubling because the computing industry is one of the fastest-growing industries in the U.S. and computing-related occupations are among the highest-paying jobs. Girls' lack of participation in this growing and important sector of society has serious consequences not only for girls and women but also for the future of technical innovation.

In the last decade, considerable research into increasing girls' participation in computing has emerged, but an up-to-date, coherent synthesis of the existing literature is lacking. This report, sponsored by NCWIT's K–12 Alliance, aims to bring together this latest research so that readers can gain a clearer and more coherent picture of **1)** the current state of affairs for girls in computing, **2)** the key barriers to increasing girls' participation in these fields, and **3)** promising practices for addressing these barriers. It is our hope that this report also will inspire and enable readers to act locally and nationally, advocating for more inclusive computing curriculum, practices, and environments.

Why is increasing girls' participation in technology and computing important?



A number of researchers, practitioners, and activists have identified several reasons why increasing the participation of girls and other underrepresented groups in computing and technology is important.

* **Improving technical innovation:** Right now, for the most part, we are missing out on the valuable perspectives that 50% of the population might bring to designing the technology of the future. A wealth of research in the past decade shows that diversity improves problem-solving, productivity, innovation, and ultimately, the bottom line. We need to ensure that the future technology we design is as broad and innovative as the population it serves (Ashcraft & Blithe, 2010; Barker & Aspray, 2006; Papastergiou, 2008; Wulf, 1999).

* **Enhancing girls' futures and reducing social inequalities:** Computing jobs are among the fastest-growing and highest-paying, yet few women are benefiting from these occupations (U.S. Dept. of Labor, 2010a, 2010b). This trend potentially exacerbates existing social inequalities and barriers to girls' future life opportunities. Increasing girls' participation in computing is important for promoting equity and ensuring that girls are able to take advantage of these jobs and the opportunities they make possible (Barker & Aspray, 2006; Margolis, et al., 2011; Miliszewska & Sztendur, 2010; Teague, 2002).

* **Ensuring a competitive workforce:** The U.S. Department of Labor estimates that between 2010–2020 there will be more than 1.4 million computing-related job openings available in the United States. At current graduation rates, we can only fill about 30% of those jobs with U.S. computing graduates. Young women bring great potential for filling this gap, yet to date, many factors dissuade them from choosing these majors and careers. Furthermore, women already employed in the technology industry are leaving at staggering rates. Failing to capitalize on this talent threatens productivity, innovation, and competitiveness (Ashcraft & Blithe, 2010; Simard, et al., 2008; Voyles et al., 2007)

What are the goals of the report?

* To present a coherent picture regarding young women's participation in computing, synthesizing the best available research into one, easy-to-access resource
* To provide an overall summary of the key barriers to girls' participation in technology and promising practices for addressing these barriers
* To serve as a reference and resource for educators, policymakers, parents, and others who wish to raise awareness and advocate for change
* To serve as a benchmark for measuring future progress in increasing girls' participation
* To identify gaps in the current literature and areas for future research

Who should read this report?

* Educators, curriculum developers, and administrators
* Educational policymakers
* School counselors
* Parents
* Researchers in gender, diversity, technology, and education
* Anyone interested in increasing equity and the participation of underrepresented groups in IT

1.4 MILLION computer-related job openings between **2010–2020**

How is this report organized?

Section 1 of this report presents publicly available national statistics and other data describing the current state of affairs in computing education and girls' participation in computing. Section 2 explores why the current state of affairs is as it is and identifies the barriers to increasing girls' participation. Section 3 provides recommendations based on research for addressing these barriers, links to practical resources for implementing these recommendations, and a quick overview of some of the most recent promising programs for girls in computing.

What are some tips for reading this report?

* Check out the Girls in IT Infographic and Executive Summary at **www.ncwit.org/thefactsgirls** for a highlight of key findings and areas for future research.

* If you are interested in more information on methodology and theoretical perspectives, see Appendices A and B at the end of this report.

* Each sub-section contains bolded summary statements that summarize the main findings in that section. Skimming through each section of the report and reading these statements will provide you with a quick sense of the overall picture.

* Read the full report from cover to cover if you're interested in a more linear explication of the problem and associated solutions. If you need only partial information, skip to the section most relevant for your purposes (see previous section, *"How is this report organized?"* and the Table of Contents, page 8).

How can I use this report to help make change?

* Spread the word and raise awareness by informing others about issues related to girls in technology.

* Advocate for and implement change efforts.

* Compare evaluations of your change efforts to those in the report.

* Identify gaps and guide plans for future research.

SCOPE AND METHODOLOGY IN BRIEF

Scope

In this report, we focus primarily on research that examines how girls *create or adapt* technology rather than on how they simply *use* technology. Research in the 1980s and early 1990s focused on technology access and the digital divide, pushing to provide educational and home access to computers, the Internet, and other technologies. Because of this research and subsequent policy and educational reforms, access divides for boys and girls have largely diminished (National Telecommunications and Information Administration (NTIA) report, 2002; Pew Research Center, 2012).

It is important to note that access and usage are still important pieces of the puzzle, however, and that the digital divide has not fully evaporated, especially when considering race/ethnicity, ability, and social class inequities (Pew Research Center, 2012). At the same time, it is important to push further to consider not only the many different ways that boys and girls use technology but also the ways in which working with computing and technology influences their current and future perceptions of computing, of themselves as technologists, and of their likelihood to consider further computing education and careers. Focusing on how girls create or adapt technologies, then, allows us to understand the way girls participate in and make sense of computing and IT work, rather than staying at the surface level of their technology use.

In a previous literature review, Barker & Aspray (2006) provide a thorough and informative look at research on girls and IT from 1994 to the early 2000s; their report extends work by Dryburgh (2000) on girls in IT in the 1990s. Our report builds on this work by examining research and evaluation from the early 2000s to the present. In some cases, however, we will reference earlier work if it still seems important to highlight or is necessary for providing past context.

We also wish to note that, to date, most research on gender and computing treats gender primarily as a variable or demographic category, where the focus is on identifying patterns related to what girls do or what boys do. The research reviewed in this report reflects this tendency. While this research is important, it typically conflates gender with sex and takes for granted a male-female binary. Many researchers have noted the limitations of this approach and the ways in which it does not account for how gender is not fixed but rather is socially constructed and produced in everyday interaction (e.g., Abbiss, 2008; Stepulevage, 2001; West & Fenstermaker, 2002). Likewise, it does not take into account how girls vary in terms of other aspects of identity, such as race and class (West & Fenstermaker, 2002; Margolis et al., 2008). In Appendix B, we delineate in more detail our theoretical perspective, elaborating on the limitations of existing gender and IT research and sketching a vision for how we might conceptualize and investigate gender in future research.

Beyond simply focusing on gender, our report also aims to consider the importance of other intersections of identity, such as race, class, and sexuality (Kvasny et al., 2009). We do wish to acknowledge that existing research on girls in IT—and thus our report—focuses disproportionately on girls broadly construed, which often obscures differences among girls, especially when it comes to differences of race, class, and sexuality. This does not represent a lack of interest in intersections of difference beyond gender but instead showcases the current power of whiteness in computing. We mark it here so that it does not remain invisible, and we call for future research that takes a more in-depth look at intersections of race, gender, class, ability, and sexuality.

Methodology and Criteria for Inclusion

To identify articles for inclusion in this report, we conducted a number of searches, primarily using Google Scholar, the Digital Library of the Association for Computing Machinery (ACM), and ERIC. We searched for articles using terms such as gender, girls, technology, information technology, computing, computer science, technology education, curriculum, media, and so on. In addition, we also solicited help from members of our K–12 Alliance, who also contributed articles from their extensive libraries. These contributions were especially important for helping us gain access to valuable program evaluations and smaller research studies we might otherwise have missed. We also looked at reference lists of articles we reviewed for additional articles. For a detailed list of criteria for inclusion in this report see Appendix A.

Definition of Terms

Because this report draws on a number of data sources and studies that define "technical" or "technology" differently, a careful discussion of terms is important. As in the "real" world, we use the following terms with some flexibility and overlap to refer to a range of activities — all of which involve the creation and adaptation (rather than the use) of technology. In general, however, the following explains in more detail how we typically use each term.

* **Computing:** In this report, we most often use the term "computing" because it functions as a more general and inclusive term that encompasses a wide range of information technology, computer science, or other computing-related activities, curricula, and professions. These all share a common characteristic: they involve participants in creating or adapting technology (e.g., developing applications/software, programming, developing hardware, coming up with new technical devices or solutions) rather than in *using* technology (e.g., using word processing, database, or other software).

* **Information Technology (IT):** We also use this term to reflect a broad range of computing-related activities. Generally, we employ the definition used by the Association of Computing Machinery (ACM), which identifies IT as a broad and diverse set of activities, but typically activities that focus "on applying the components of information technology to solve a business information problem, such as network or database administration" (**www.acm.org**).

* **Computer Science (CS):** In using this term, we also employ the definition used by ACM, describing computer science as "an academic discipline that encompasses the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society" (**www.acm.org**).

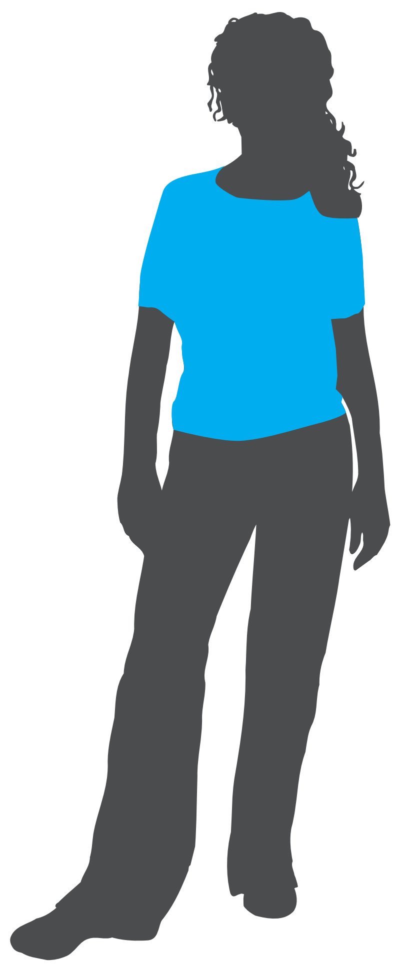
* **Computational Thinking (CT):** This more recent term refers to the marriage of critical thinking and computing power. Though there are various definitions of CT, the Computer Science Teachers Association (CSTA) and the International Society for

Technology in Education (ISTE) have defined it for K–12 as including nine fundamental computer science concepts: data collection, data analysis, data representation, problem decomposition, abstraction, algorithms and procedures, automation, parallelization and simulation. The term is especially meant to highlight how computer science concepts appear in various combinations in many problems and tasks across many subject areas, making it possible to incorporate CT into all grade levels (**www.iste.org/computational-thinking** and **www.csta.acm.org**). In this report, we will primarily use this term when talking about infusing computing concepts throughout the curriculum in a variety of subject areas.

* **Technology or Technical:** Unless stated otherwise, these terms also refer to involvement in the creation or adaptation, not use, of technology.

* **Science, Technology, Engineering, Math (STEM):** Some studies looked at girls in technology, while some studied girls in STEM more broadly. When possible, we report findings specific to technology. We report on broader STEM research only when it may provide insight or fill a gap in our knowledge about girls' participation in computing.

Note about demographic terms: *When using terms such as White, Black, African American, Hispanic, and Latino, we generally retain the terms used by the original researchers; therefore, variation in these terms will appear throughout the report.*



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Section 1:

Girls in IT: What is the current state of affairs?

Section Snapshot

In this section, we take a look at national, publicly available data to examine how girls are currently participating in various aspects of computing.

* **Computing and Computer Science Education: What do the national, state, and local pictures look like?**
* **Girls and Computing in K–12: In what kinds of computing education and activities are girls participating?**
* **AP Tests and Intent to Major: What are girls' plans for pursuing computing higher education?**
* **Graduation Rates: How do these patterns play out in post-secondary education?**

Computing and Computer Science Education: What do the national, state, and local pictures look like?

Before exploring the current state of girls in IT, it is important to understand the larger picture surrounding computer science education in general. This understanding helps illuminate the larger context of computing education, the ways it serves or doesn't serve all students, and how girls' experience fits within this larger picture.

Computing and computer science education is on the decline. In their comprehensive report, "Running on Empty," the Association for Computing Machinery (ACM) and the Computer Science Teachers Association (CSTA) provide a detailed look into the current state of computing education in K–12 classes in the United States (Wilson, Sudol, Stephenson, & Stehlik, 2010). They detail how, despite the increasing pervasiveness of technology and the growing need for computer science expertise, U.S. computer science education is on the decline. Consider the following key findings from the report:

* Based on a survey of CSTA members, the number of schools offering introductory computer science courses is down by 17% and the number of schools offering AP computer science courses is down by 35% since 2005.
* Only nine states currently allow CS to count for a required math or science course.
* Two-thirds of states have few or no computer science educational standards for secondary schools.

* Currently high schools in the U.S. treat computer science as an elective or extracurricular activity, if it *even exists* at all; currently *no* states require computer science coursework.

As Barker & Aspray (2006) observe, the absence of computer science in the mainstream curriculum and its presence in informal curricula "give the implicit message that computer science is superfluous, something neither important nor required, but there to learn about if one has the inclination" (p. 16). Parents, counselors, and teachers also emphasize the importance of more traditional science courses like chemistry, making students more familiar with (and more successful in, according to Clark Blickenstaff, 2005) these more established sciences when they enter college. This prior experience further discourages students' future enrollment in CS courses. Because boys tend to have more *informal* opportunities for computer science experience, the lack of more formal opportunities in U.S. curriculum especially impacts girls, underrepresented minorities, and students from underresourced areas (Jepson & Perl, 2002; Margolis et al., 2008).

Preparation for teachers is lacking. State certifications for computer science teachers either do not exist or have serious shortcomings (Simard et al., 2010; Wilson et al ., 2010). Several states have begun providing CS endorsements, however, and this can help improve teacher preparation (see Section 3, Addressing the Barriers: What can legislators and policymakers do?) Furthermore, although model curriculum for CS courses does exist (see www.exploringcs.org), because few states have CS standards, the infrastructure and courses necessary for implementing this curriculum often do not exist. As Goode (2008) observes, many teachers, counselors, and administrators are not familiar with computing or CS and are unsure of where it fits in the curriculum. Not only does this create problems for implementing computing curriculum and courses, it also means that students often are not made aware of or encouraged to take these classes when they are offered (Goode, 2008; Howe et al., 2007). Also, many teachers of primary and secondary education are women who, to date, have low levels of CS and IT training (Barker & Aspray, 2006). Teachers also are influenced by cultural biases about who does (and does not do) CS work and are significantly affected by the infrastructure and lack of resources for CS education available in their schools (Barker & Aspray, 2006; Margolis et al., 2008).

Computer science often is conflated with computer literacy. Computer science education continues to be confused with computer or technological literacy, which focuses primarily on the use of technology rather than its creation. This confusion makes it difficult to distinguish and advocate for programs that teach the 21st-century computing skills students need for actually inventing and developing the technologies of the future. As a result of this confusion, many educators and administrators think that by offering computer literacy courses, they are providing students with the technological skills they need. However, while these courses are important, they are not enough (http://csta.acm.org/Curriculum/sub/K12Standards.html).

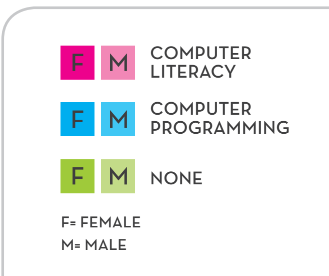
In **Section 3,** we return to these issues, highlighting recommendations not only for increasing girls' participation in IT but also recommendations that will improve the state of computer science education in general. We now turn to look at how girls are participating in the opportunities for computing education and activities that *do* exist.

Girls and Computing in K–12: In what kinds of computing education and activities are girls participating?

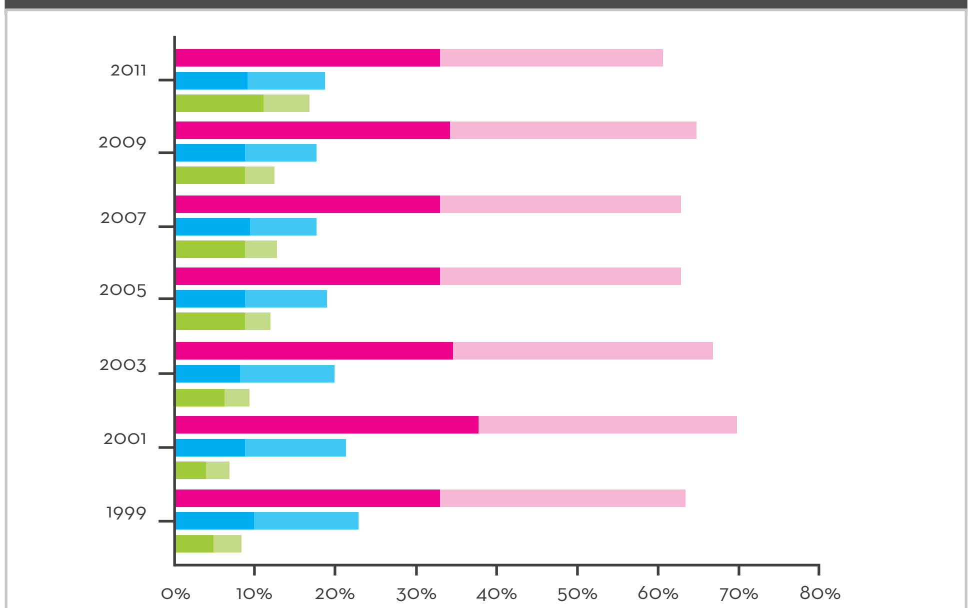
According to a survey that is administered with SAT exams, both male and female college-bound high school students report significantly less exposure to computer programming courses than to computer literacy courses.

* More than 60% of the 1.5 million students surveyed who reported no high school computer coursework or experience at all were girls.

* Recent data, however, do indicate that girls' representation among students with programming experience has increased slightly since 2005.



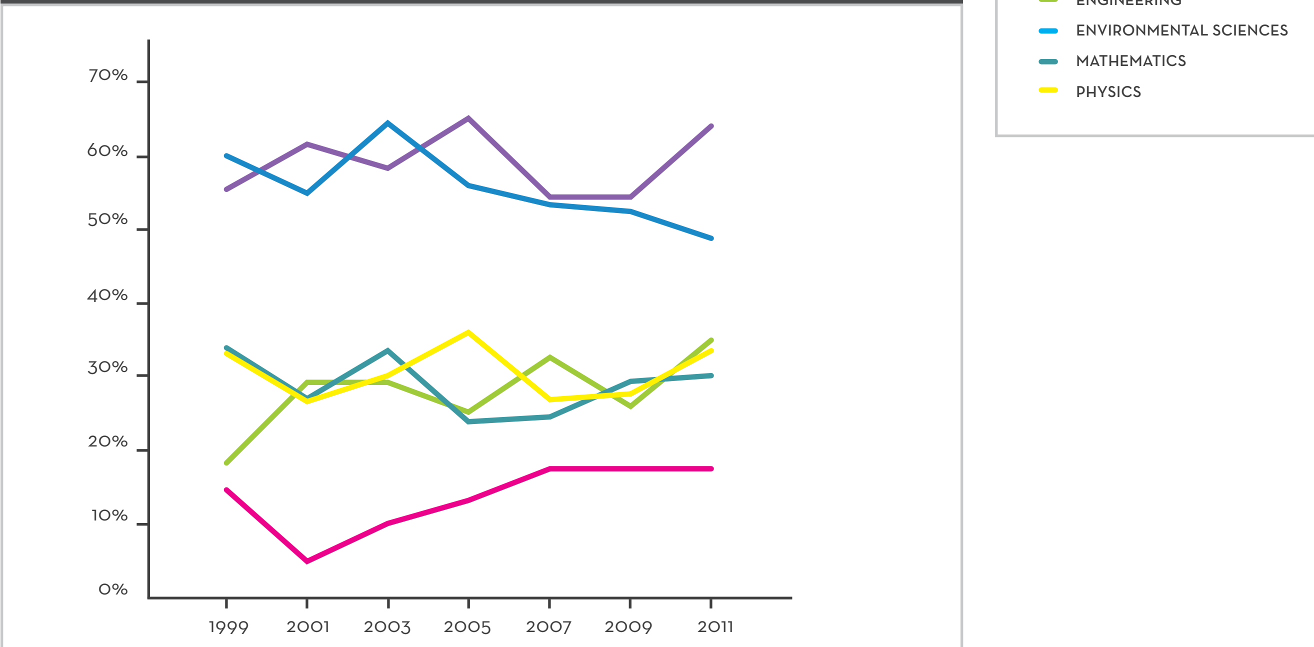
PERCENTAGE OF STUDENTS REPORTING COMPUTER COURSEWORK/EXPERIENCE IN HIGH SCHOOL, 1999–2011



© NCWIT. Source: The College Board, Archived SAT Data and Reports, 1999-2011.

Each year, approximately 1,500 of the top science and engineering fair students from 51 countries compete for over $4 million in prizes and scholarships in the Intel Science and Engineering Fair (ISEF), making it the largest pre-college science competition in the world. As such, it is an important metric for understanding girls' participation in creating technology. Since 1999, between 43% and 49% of all competitors have been girls. Despite a relatively recent rise (2001-2007), girls' participation still remains lowest (at 17%) for computer-science projects compared to other subjects.

FEMALE PERCENTAGE OF PARTICIPANTS, INTEL SCIENCE AND ENGINEERING FAIR (ISEF) 1999-2011



© NCWIT. Source: Intel ISEF Participation Statistics (unpublished).

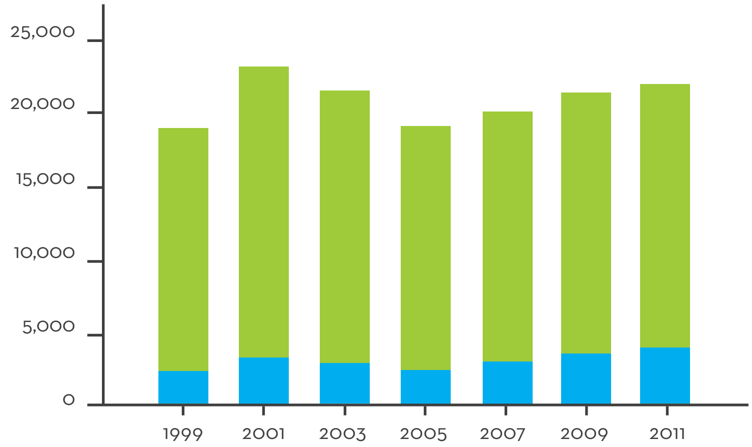
AP Tests and Intent to Major: What are girls' plans for pursuing computing higher education?

* In 2011, more than half of all Advanced Placement (AP) test-takers were female (56%).
* That same year, approximately 46% of all AP Calculus test-takers were female. However, only 19% of the students who took an AP Computer Science exam were female.
* Each year since 1999, the AP Computer Science exam consistently has had the lowest female percentage of any of the 37 AP exams, hovering at 19% or lower.

M MALE

F FEMALE

NUMBER OF ADVANCED PLACEMENT (AP) COMPUTER SCIENCE TEST-TAKERS BY GENDER, 1999–2011



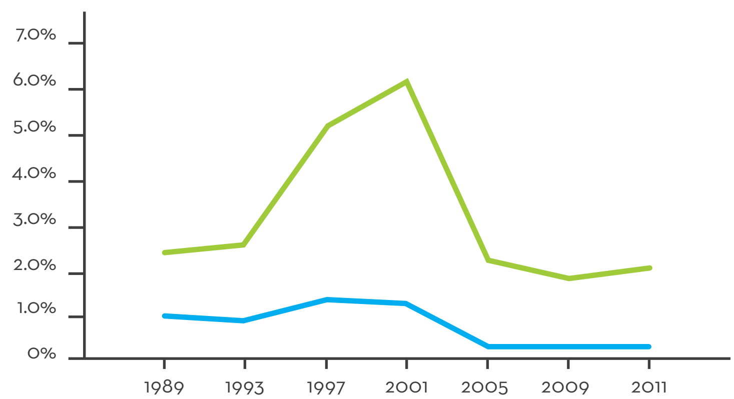
© NCWIT. Source: The College Board, AP National Summaries, 1999-2011.

Since the turn of the 21st century, interest in the CS major among male and female college freshmen has decreased steadily, with only about 2% of male freshmen intending a CS major, compared with about 0.3% (3/10 percent) of female first-year students.

M MALE

F FEMALE

PERCENTAGE OF AMERICAN FRESHMEN INTENDING TO MAJOR IN COMPUTER SCIENCE: A LONGITUDINAL LOOK, 1989–2011



© NCWIT. Source: Higher Education Research Institute, *The American Freshman: Forty-Year Trends 1966-2006*; Higher Education Research Institute, *The American Freshman: National Norms Fall 2011*.

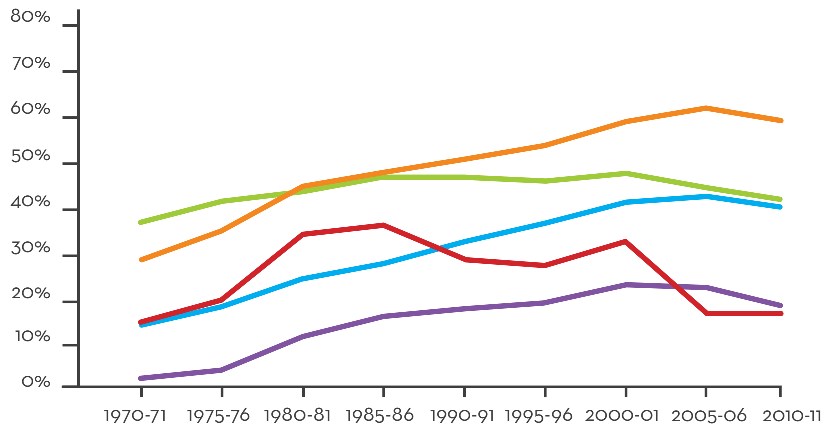
Graduation Rates: How do these patterns play out in post-secondary education?

Women earn...

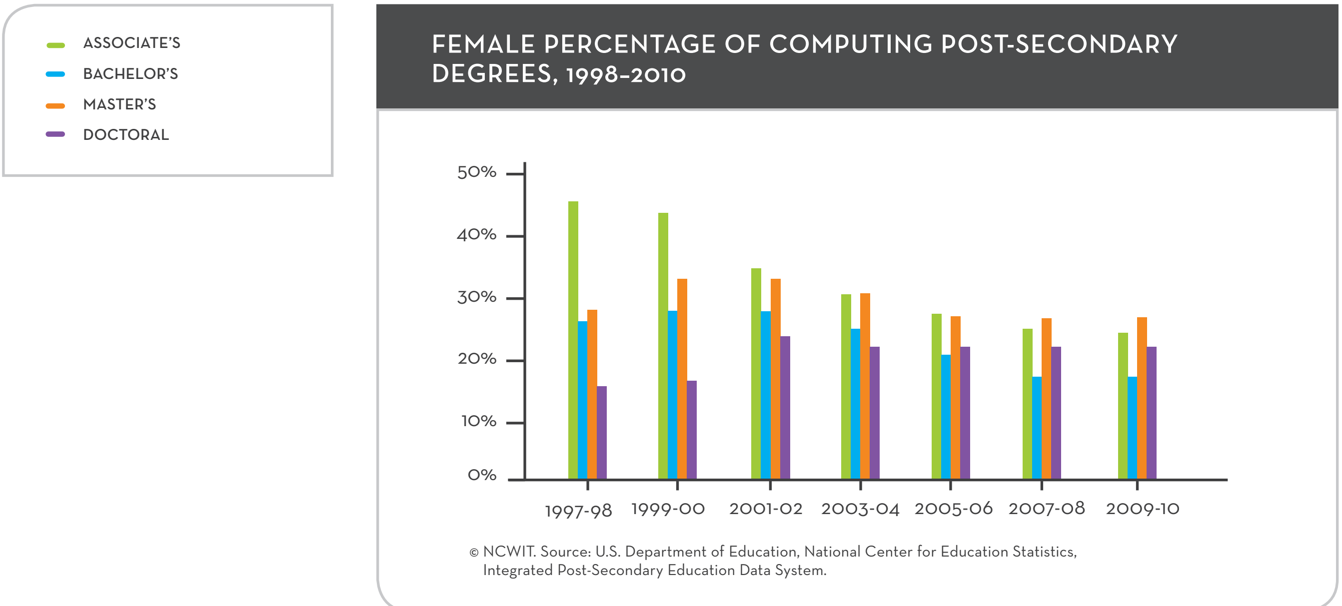
* **57%** of all undergraduate degrees
* **52%** of all math and science undergraduate degrees
* **42%** of all math and statistics degrees and **40%** of all physical science degrees
* **BUT** only **18%** of all computer and information sciences undergraduate degrees

Women's share of undergraduate degrees is lower in computing than in any other STEM field.

FEMALE PERCENTAGE OF SELECT STEM UNDERGRADUATE DEGREE RECIPIENTS: A LONGITUDINAL LOOK



© NCWIT. Source: U.S. Department of Education, National Center for Education Statistics, Integrated Post-secondary Education Data System.



* At 18%, the proportion of bachelor's degrees in computing received by women in 2011 was lower than for associate's (25%), master's (27%), or doctoral (22%) degrees in computing.

* The female percentages of associate's and bachelor's degrees in computing have decreased over time. In contrast, the female percentage of master's degrees has held steady the past two years, while the female percentage of doctoral degrees in computing has held steady since 2002.

Over the last 20 years much has been done to encourage female students to choose computing courses and computing careers. Some instances of positive effects have been reported, yet the proportional disparity in gender in this discipline continues to grow (U.S. Dept. of Labor, 2010; Lang, Craig, Fisher, & Forgasz, 2010). It is troubling to many that computing continues to be viewed as "a boy-thing" (Klawe, 2002). In the next section, we take a look at some of the barriers to increasing girls' participation in computing.

Section 2:

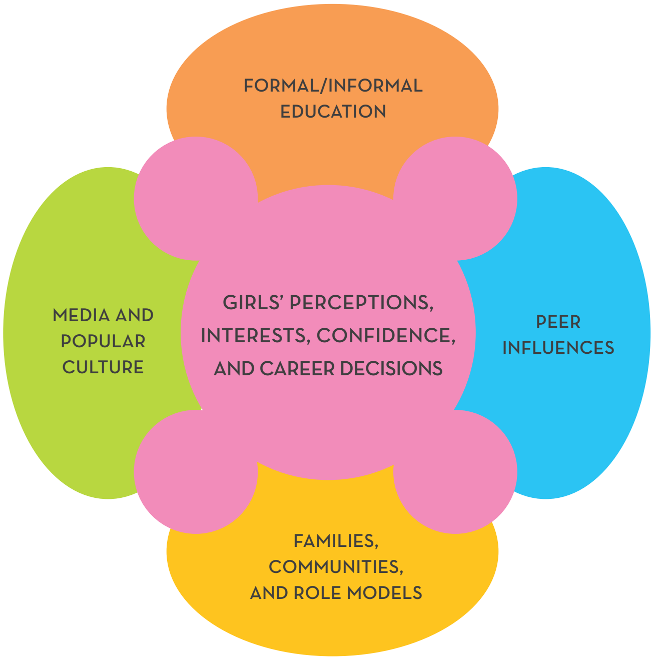
Identifying Barriers: *Why* the Current State of Affairs?

Section Snapshot

In this section, we explore several contexts, identifying the key factors in each that affect girls' participation in computing.

* **Formal and Informal Education: Computing curriculum that is disconnected from student interests and environments that are uncomfortable for girls**
* **Families, Communities, and Role Models: Unequal opportunities and early experiences**
* **Peer Influences: "Sometimes it's hard to be the only girl"**
* **Media and Popular Culture: Computing as masculine and "geeky"**
* **Summing It Up: Girls' perceptions, interests, confidence, and career decisions**

Recent research has identified several key social and structural factors that influence girls' participation in computing, often deterring them from choosing future education or careers in technology. The following model depicts the key contexts in which these factors occur. We have placed "Girls' Perceptions, Interests, Confidence, and Career Decisions" in the center of this model to highlight the fact that girls do not come by these perceptions, interests, and career decisions innately or in a vacuum. Indeed, these are shaped by the larger society and local environments in which they learn about computing and technology, and this significantly influences what appears to be their "choices" to pursue computing and computing careers.



In what follows, we take a closer look at the factors in each of these contexts and illustrate how they shape girls' participation in computing.

Formal and Informal Education: Computing curriculum that is disconnected from student interests and environments that are uncomfortable for girls

A wealth of broader educational research rooted in constructivist, constructionist, and culturally relevant learning theories has long emphasized the importance of connecting instruction to students' interest and prior knowledge and of using active and collaborative learning pedagogies (e.g.,Vygotzky, 1978; Papert, 1980; Harel & Papert, 1990; Harlen, 1998; Ladson-Billings, 2006). This research highlights how these approaches are important not only for improving learning for girls and other underrepresented students, but for all students. More recently, some of this research has focused specifically on how curriculum and teaching practices in science-related fields do not employ these pedagogies and, therefore, contribute to girls' lack of interest in these areas (e.g., AAUW, 2000; Clark & Blickenstaff, 2005; NAPEEF, 2009; Sadker & Sadker, 1994). In sum, these factors include: **1)** curriculum that is irrelevant, **2)** pedagogies that discourage collaboration, **3)** lack of opportunities to take risks and make mistakes, and **4)** heavy reliance on lecturing instead of active, hands-on, project-based learning. This research also identifies more informal aspects of classroom culture, such as student-student and teacher-student interactions that discourage girls' participation.

At the time of Barker & Aspray's (2006) previous literature review (see Scope on page 4), few studies had been done specifically on the computing classroom, but those that had been done found patterns similar to those mentioned above in science classrooms. Likewise, research into undergraduate computing classrooms also has observed similar problems in these classrooms, such as irrelevant curricula and pedagogies that discourage risk-taking and collaboration (e.g., Barker & Garvin-Doxas, 2004).

We build on this work, taking a look at some of the latest findings about curriculum and pedagogy in existing computing and computer science classrooms. In general, this research shows that computing classrooms still employ many pedagogical practices that are not based in sound learning theories. While these curricula, pedagogies, and classroom cultures can particularly dampen many girls' interests, they also can dampen many boys' interest in these areas. As a result, improving curricula and pedagogy will improve computing courses for all students. In what follows, we elaborate on these most recent findings.

Computing curriculum is still irrelevant and encourages negative perceptions of the field; this hinders girls' interest in these courses. Though some curricular improvements have been made in specific programs (see Section 3 of this report for promising curricula and programs), computer science courses still routinely fail to make computing curriculum relevant for students (e.g., Anderson, et al., 2008; AAUW, 2000;

Goode et al., 2006; Goode, 2007; Margolis et al., 2008; Lasen, 2010). Computing is often taught in the abstract, preventing students from recognizing how technology can help address relevant social problems. This kind of curriculum also reinforces a view of computing as a lonely, isolated, machine-focused set of tasks (Clayton et al., 2009; Margolis et al., 2008; Papastergiou, 2008).

This lack of relevance is troubling because making relevant connections is particularly important for increasing girls' interest in computing courses and careers. Interview research with women who had chosen computing careers revealed that these women credited courses that tied computing activities to girls' real-life experiences as important for correcting their misperceptions and changing their attitudes about computing careers. They suggested that these were important components of efforts to increase girls' interest in technology (Teague, 2002). These findings are corroborated by several other studies, including a recent survey of 937 women currently working in technical occupations (Liston, et al., 2008). When asked what kinds of experiences motivated them to pursue these careers, they identified hands-on experiences, relevant curriculum, engaging staff, and project-based learning opportunities as critical for their decisions to pursue computing.

While the previous studies surveyed adult women about their perceptions of what worked when they were girls, a recent survey of 1,453 Australian female secondary students (131 girls were "Takers" of advanced IT classes; 1,322 were "Non-Takers") found similar results. The Non-Takers identified two primary reasons for not taking IT classes: **1)** "the subjects are boring" and **2)** "the subjects would not be helpful to me in my chosen career path" (Anderson et al., 2008). Focus group interviews with these girls revealed that one reason "Non-Takers" perceived these subjects to be boring was due to their experiences in earlier secondary school IT courses which often had been taught by teachers with limited preparation and consisted of "mundane, repetitive tasks" (Lasen, 2010). Furthermore, the girls perceived the courses to be almost exclusively about programming even though they were not. Interestingly, both Non-Takers and Takers expressed an aversion to programming, but the Takers had more awareness about the creative aspects of the IT courses, and this is what attracted these girls to these IT courses. When interviewers described these aspects of the course to Non-Takers, many responded positively to these descriptions. It is important to note that relevant curriculum also enhances many boys' interests in these courses. As a result, improving computing curriculum in this way will benefit *all* students.

Teachers often privilege independent work and discourage, or even chastise, collaborative work. It still seems to be the case, especially in formal computing classrooms, that collaboration is sometimes equated with cheating or plagiarism. This is true at both the secondary and undergraduate level (Barker & Garvin-Doxas, 2004; Clark Blickenstaff, 2005; Margolis et al., 2008). In part, this stems from larger social factors in U.S. culture and education that emphasize the importance of individual achievement over collaboration, as well as evaluation mechanisms such as standardized testing that measure and reward individual accomplishments (Margolis et al., 2008). Collaboration, however, is important for student learning; pair programming, in particular, has been shown to improve students' computing skills and improve girls' experiences in computing courses (McDowell et al., 2002; Werner & Denner, 2009). While much of this research has been done at the undergraduate level (e.g., McDowell et al., 2002; McDowell et al., 2006), additional research has shown positive effects of collaboration for girls in computing classes (e.g., increased persistence in the face of debugging challenges; increased networks of support) (Marcu, 2010; Werner & Denner, 2009). How collaboration takes place is important, however, since merely having students work together is not enough to ensure positive results (Barron, 2004; Denner & Werner, 2007; Denner & Werner, 2007; Werner & Denner, 2009). Teachers need to have the training and resources necessary for creating the conditions that result in productive collaborations (See Werner & Denner, 2009 for more information on the kinds of interactions that support productive collaboration. Also see Section 3, A Quick Glance at Promising Programs, for examples of programs implementing these strategies).

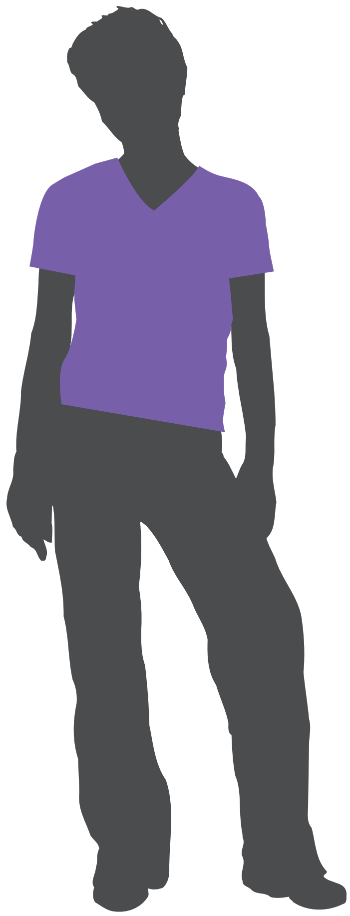
Curriculum and pedagogies sometimes emphasize *speed, breadth, and task competence* rather than *depth and fluency.* Fluency involves an understanding of underlying concepts and an ability to transfer this understanding to new problems and situations (Cunningham, 2011). Focusing instead on speed, breadth, and competence at isolated tasks can negatively impact both male and female students who prefer to delve into curriculum more deeply (Clark Blickenstaff, 2005; Crombie et al., 2002; Irani, 2004). Clark Blickenstaff's (2005) literature review, while primarily focused on STEM courses more broadly, illustrates that girls and women were more successful in collegiate science courses when they took high school courses that focused on depth of the subject matter. Likewise, a survey of 8,310 college students in biology, chemistry, and physics classes revealed that both male and female students who reported covering at least one major topic in depth (e.g., for a month or longer) in high school earned higher grades in college science courses than did students who reported no coverage in depth (Schwartz et al., 2009). These studies, of course, are not specific to computing, and further research would do well to investigate how these patterns play out in computing classrooms.

Unconscious biases about who has "innate" talent or who has a "flair" for computing have a profound effect. Teachers and other adults often have biases in terms of who they believe has a "flair" for computing (AAUW, 2000; Margolis, et al., 2008). Teachers sometimes reinforce that while girls work hard, boys are more natural with the computer or have more interest or skill (Barker & Aspray, 2006; Margolis et al., 2008; Voyles et al., 2007). These perceptions and interactions are important because perceived support from teachers has a direct effect on girls' interest in computing classes and careers (Clegg, 2001; Denner, 2011).

It is also important to note how these dynamics tend to vary by race and/or class. According to a survey of 852 girls (67% Caucasian, 15% African American, 15% Hispanic, 6% Asian, and 5% Other) conducted by Girl Scout Research Institute (2012), 62% of African American girls reported that teachers were less supportive of their career interests, while 73% of White girls felt that teachers were supportive of these interests. Margolis et al., (2008) also illustrates in great detail how this plays out in particular ways for students/girls of color, especially in underresourced communities and school districts. Teachers often hold particularly low expectations of students in these communities, assuming a lack of interest or parental support, not recognizing that this perceived lack of interest or support is more about a real lack in the opportunities available to these students and their families. Students are profoundly impacted by these actual and perceived expectations (Denner, 2011; Margolis, et al., 2008; Vekiri, 2010; Vekiri et al., 2008).

Girls' experience the computing classroom environment as unwelcoming or uncomfortable. This pattern has long been charted in sciences where many teachers and students believe science is "simply a boys' subject" (Clark Blickenstaff, 2005). While this has improved somewhat in science in general, societal beliefs about computing as masculine are still pervasive and can surface in computing classrooms (e.g., Margolis et al., 2008). Not only do teachers sometimes hold this belief, but the classroom is often dominated by boys, sometimes making it uncomfortable for girls (e.g., Goode, et al., 2006; Goode, 2007). In a mixed-methods study of 158 Canadian students, girls indicated in interviews that their interest in computing classes was influenced by social factors like their perceptions of the climate of the computer lab and whether classes were being dominated by boys or by the presence of friends (Jenson, de Castell, & Bryson, 2003). Similarly, in the Girl Scout Research Institute (2012) survey mentioned above, nearly half (47%) of all girls said that they would feel uncomfortable being the only girl in a group or class (Girl Scout Research Institute, 2012).

The physical environment also has a profound effect on girls' comfort in the classroom. For example, Cheryan and her colleagues (2009, 2011a) found that rooms decorated with images and objects associated with "geeky" stereotypes (e.g., Star Trek and Star Wars images and paraphernalia, video game boxes, comics, science fiction books, stacked soda cans, electronics, and computer parts) are less appealing and communicate a lower sense of belonging to young women, as well as to young men who do not resonate with these "geeky" characteristics. Likewise, virtual classrooms decorated with these stereotyped images lead women to feel that these environments are not for them. This research has shown that stereotypical environments such as these measurably reduce young women's interest in declaring a computing major and their anticipated success in computing. While this research was conducted with undergraduates, there is reason to suspect that similar effects occur for middle and high school girls.



Similarly, a good deal of research has found that teachers and other adults can confuse students' prior experience with innate ability, failing to realize that other students may seem less able simply because they've had less experience. This prior experience and its resulting confidence are often unconsciously rewarded in both secondary and undergraduate CS classes (Barker & Garvin-Doxas, 2004; Margolis et al., 2008). Because girls often have later exposure to introductory CS courses (Barker & Aspray, 2006; Barron, 2004; Crombie et al., 2002), girls may not gain this prior experience.

Families, Communities, and Role Models: Unequal opportunities and early experiences

As Barker and Aspray (2006) note, we know that families, communities, and role models play a significant role in girls' and boys' decisions about education and career, but exactly how this plays out in girls' decisions to pursue and persist in computing is much less clear. Parents and older siblings have significant influence as role models and in the types of messages or beliefs they communicate to girls both implicitly and explicitly. More recent research has shown that media imagery of computing as a solitary and "geeky" profession is also often reinforced by families (Clayton, von Hellens, & Nielsen, 2009). Additional recent research in the exact role families and communities play has emerged but findings are still mixed.

"My dad owns a computer company so it's good to know certain things with computers to help other people out when their computers shut down or do things."

young girl, Denver, CO (GSRI, 2012)

Parental or familial expertise or career in computing can play an important role, but the exact role is unclear or varies. In one survey of 937 women currently working in computing occupations (Liston, et al., 2008), 38% of the women had fathers who worked in a STEM field and 10% had mothers who did. Barron (2004) found that 75% of girls reported having a parent or family member in the computing field as a reason for choosing to take a programming course; only 29% of the boys chose this as a reason for taking the course. In contrast, however, Gal-Ezer, Shahak & Zur (2009) surveyed 229 high school students to better understand why CS continues to be male-dominated throughout the western world. The authors found that parents encouraged their sons to pursue CS courses in high school more than their daughters but that parents' careers were not a significant factor in students' decisions to take CS for either boys or girls. Cultural differences may be at play here as this study was conducted in Israel. Regardless, the question remains open since we do not really know how many girls (or boys) who do not choose computing careers might also have a parent in the field and cite this as a reason for *not* selecting this career.

"My dad…works with computers a lot. It's really interesting to him. I don't find it as interesting because he does it."

teen girl, Seattle, WA (GSRI, 2012)

Along these lines, some research suggests that seeing male family members in computing can reinforce perceptions that this is a masculine field. In their literature review, Cozza (2011) noted that the prevalence of "relatives — most often fathers or brothers — who have taken up careers in computer science, or who have greater familiarity with the computer, may reinforce the stereotype of technology as masculine" (p. 323). Additional studies have found some empirical support for this claim. In focus groups conducted with girls and in other literature that they reviewed, the American Association of University Women (2000) found that fathers were much more likely to be seen as computer experts than mothers. In another study, 67% of both male and female students surveyed claimed that their mothers did not know much about computers; the same students claimed that only 44% of fathers did not know much about them. The actual skill levels of these parents are unknown, as is how these perceptions of their parents' abilities affected these students' career choice. Nonetheless, we do know from a wealth of broader research about the importance of role models that perceptions of parents and other adults as role models often do affect children's career choices. These and similar findings demonstrate that students looking for a tech-savvy female role model at home may find it more difficult to find one (Moorman & Johnson, 2003).

Parental or familial support and encouragement has a profound effect on girls' choices to persist. While the exact influence of having a parent or family member in computing is unclear, parent or family encouragement to pursue computing seems decidedly important. For example, Barron (2004) found that 75% of girls who had taken a programming class had been encouraged by parents or other family members to take the course; only 32% of the boys said that they had been encouraged by a family member to take the course. In the previously mentioned study of 937 women in computing occupations, women most frequently chose their father (37%), mother (29%), or spouse/partner (24%) as the most influential person in their decision to pursue a computing career (Liston et al., 2008). Zarrett and colleagues (2005, 2006) also found that being advised by a parent, teacher, or peer to pursue an IT occupation was an important factor in determining girls' aspirations to an IT career. A survey of 954 U.S. high school and college women also found that encouragement and direction provided by parents was more influential than that of counselors or teachers (Meszaros, et al., 2009) and that girls were significantly more likely than boys to seek input about careers. In contrast, another study of 300 middle school students found that perceived teacher expectations and support were more strongly associated with girls' sense of computing self-efficacy, while parent expectations and support were more important for boys' sense of self-efficacy (Vekiri, 2010). They speculate that this may be due to the fact that girls in their study and other studies tend to have less home experiences with computing and also report less encouragement from parents (e.g., Barker & Aspray, 2006; Vekiri & Chronaki, 2008); therefore, teachers and school experiences may have a greater impact for girls than boys.

In their survey of 1,434 undergraduates (31% female and 69% male; 59% White, 15% Asian, 15% Black, 5% Hispanic, less than 1% Native American, and 5% Multiracial), Guzdial et al. (in press) found that encouragement was the driving factor in how likely female students were to complete a computing major/minor and to choose a computing career — more important than girls' confidence in and perceptions of their ability. This was also true for Black students (not disaggregated by gender). For White males, both perceptions of ability and encouragement were important factors.

In her study of 140 girls (primarily Latina), Denner (2011) found that perceived parental support had a direct influence on the extent to which girls value computing (see it as important and relevant), which in turn had a powerful impact on their interest in computing. Qualitative data from this study indicated that girls consider their parents and other family members as the greatest influence on their career interests (Denner, 2009). Other studies have found that only certain kinds of parental support predict students' persistence in computing (e.g, Larose et al., 2008). As Denner (2011) suggests, future research would benefit from more sensitive measures of parental support that can distinguish between these different types of support and how these affect interest in computing of girls of different races and ethnicities.

Early exposure to computers and computing at home plays a role, but the key factor seems to be the kind of computing experience. As Barker & Aspray (2006) observe, past studies have generally found that while computer use at school is fairly similar between boys and girls, use at home presents a different picture. In general, the studies they reviewed found that more boys than girls used computers at home, boys were younger than girls when they began using computers, boys used the Internet more than girls, and boys used their computers at home on average more hours per day than girls. In contrast, some studies have found few gender differences in these activities. This variation in findings is probably due to differences in the specific populations studied, such as age and other demographics. Gender differences in computer usage also do tend to increase as children grow older (e.g., Barker & Aspray, 2006; Vekiri & Chronaki, 2008).

As noted earlier, the focus of this report is not on computer usage, but here we do present findings from a few recent usage studies because past studies have found that early usage has been shown to improve success in future computing classes (Barker & Aspray, 2006). Consistent with these past findings, Varma (2009) conducted in-depth interviews with 150 undergraduates about their pre-college computer usage and found that significantly more males reported early exposure to computers at home (63% male versus 37% female); conversely, significantly more females reported later exposure to computers (35% male versus 65% female). Colley & Comber (2003) found that there was a gender difference in the pattern of ownership of a home games computer, with more boys than girls owning one, but that there was no significant gender difference in home PC ownership. Likewise, in surveys, peer focus groups, and at-home interviews of youth in England, Kent and Facer (2004) explored difference in computer usage and access at home based on gender, age, and socioeconomic backgrounds. They found that boys were more likely to use computers at home for fun and for Internet activities; girls were more likely than boys to use the computer at home for writing. A recent study of students in Greece confirms earlier research, finding that opportunities for early familiarization with computing in the home is a key factor differentiating boys' and girls' motivation for studying CS (Papastergiou, 2008).

Barron (2004) conducted one of the few existing, comprehensive studies of males' and females' experience with "creative production" of technology in the home (creating with technology rather than just use) and found that higher levels of experience with creative production was a significant factor in later success in computing courses. More boys had high levels of experience than girls, but when controlling for gender within experience level groups, most differences in terms of kinds of activities, confidence, interest, and motivation disappeared. The only exception was in programming. Significantly more boys with high levels of experience had more programming experience than girls with similar levels of experience. In surveying the students in their program, Bruckman and colleagues (2002) also found that boys had much more early experience with programming than girls. Interestingly, a family member's encouragement and a family member who had professional programming experience were key factors influencing girls to take a programming course (Barron, 2004). This was not the case for the majority of boys.

Barron (2004) also found that girls with higher levels of experience reported higher levels of confidence, but boys reported being confident regardless of experience. In terms of interest, boys wanted to learn more regardless of their experience level, but more-experienced females expressed a stronger interest than less-experienced females to learn more. Both experience and sex were significant factors in whether girls and boys considered majoring in computer science and becoming a computer programmer, computer network specialist, or computer teacher. Experience was the only factor in whether or not girls and boys considered becoming a web designer. As Barron observes, this likely reflects the fact that web designer is a less gender-specific career, as there are relatively similar numbers of women and men currently in this occupation (U.S. Dept. of Labor, 2010).

The role of the larger community has a significant impact on early exposure to computing activities and role models. While the research discussed thus far illustrates that girls, in general, still tend to have less early exposure to computing activities than boys, these trends also vary by community and are affected by dynamics of race and class. As Barker & Aspray (2006) observed, the community in which girls grow up plays a profound influence on the kinds of computing activities available (e.g., in extracurricular and community-based programs), their exposure to other girls (or boys) who participate in these activities, their exposure to adults who work in these professions or other role models, and the resources at home and school for engaging in these activities.

While the digital divide has narrowed in many ways, access is still a problem in less affluent and some urban or rural areas, and this divide significantly shapes girls' and boys' computing experiences in these communities (e.g., Barker et al., 2006; Margolis et al., 2008; Zarrett, 2006). As Margolis and colleagues (2011) explain, "across the United States, only a narrow, largely homogenous band of students—frequently those from families able to provide computers, Internet access, robotic kits, a plethora of software, and parental knowledge—are introduced to computer science. Many others, who lack high-quality schooling opportunities and substantial family resources, are relegated to the shallow end of computing skills" (p. 68). This perpetuates inequities in computing experience, especially for girls of color and girls from less affluent communities. These inequities in experience then translate to phenomena like lower pass rates on Advanced Placement CS tests. Females have lower pass rates than males and Latina and African American females have lower pass rates than White females (College Board, 2012). These kinds of discrepancies are due, in large part, to a phenomena Margolis and colleagues (2008) call "participatory preparation," where White, middle class boys are more often exposed to informal opportunities in computing, and then later appear to be more "naturally" engaged or talented because they have been encouraged into more of these experiences.

The community also has a profound effect on the availability of and exposure to role models. A wealth of research in science education in general, and in computing education in particular, finds that role models are important factors influencing girls' decisions to pursue computing (e.g., Barker & Aspray, 2006; Clark Blickenstaff, 2005; Cozza, 2011). Such role models, however, are often less available for those students who do not come from affluent communities, positions of privilege, or school systems that provide better access to computing courses. One study found that White girls (61%) are much more likely to know someone in a STEM career, compared to African American (48%) and Hispanic (52%) girls (Girl Scout Research Institute, 2012). Margolis et al (2008, 2011) also identify the lack of role models as a problem for youth and girls of color, and indeed, in their Los Angeles-based program, students specifically commented on the importance of seeing young Black women doing interesting robotics work during a spring presentation program.

While girls need to see women like themselves in these roles, it would also be a mistake to think that girls only can relate to other girls and women (Cheryan & Plaut, 2010; Cheryan et al., 2011b). A combination of diverse male and female role models is best. Many women and girls also describe the importance of male role models, and it would be a mistake to think that people cannot relate to each other across lines of gender and race (Liston, et al., 2008). One of the most important characteristics of a role model is that girls perceive these role models as "relatable" and similar to themselves. Gender and race are most certainly important factors in perceived similarity, but they are not the only factors. This perceived similarity to people in the field and a feeling that one will "fit in" is a major factor in choosing a major and a career (Cheryan & Plaut, 2010; Cheryan et al., 2011b).

Peer Influences: "Sometimes it's hard to be the only girl"

As in all areas of K–12 education, peer influence matters. Barker and Aspray *(2006)* explore the impact of peers as a very "powerful influence on children's beliefs and behavioral choices" (p. 34). The authors note in their review of more general literature on peer influences that these are especially strong during teenage years because students begin to display an even greater need to perform certain persona that their peers deem to be appropriate, cool, or acceptable. Below, we take a look at more recent research specific to peer influence and computing.

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"I think sometimes girls don't want to go into STEM careers because women who do that are nerds and not the kinds of girls that guys are looking for sometimes."

teen girl, Seattle, WA (GSRI, 2012)

Peer influences can have a positive effect on girls' plans to pursue computing. In a survey of 140 middle school girls (approximately 74% Latino, 17% White), Denner (2011) found that perceived support from school peers (and teachers) had a direct effect on girls' interest in computing classes and careers, more so than support from parents. Similarly, Goode and colleagues (2006) highlight the importance of building supportive networks for girls and recruiting groups of girls who already know each other into computing classes. Cozza (2011) also notes that youth consider peers as guides, especially when they lack adult mentors or role models. Other studies have also found that peer support is an important factor (Jenson et al., 2003; Moorman & Johnson, 2003; Teague, 2002). As a result, peer support and peer and "near-peer" role models can have a very positive effect on girls' interest in computing (Cozza, 2011). By providing real-life examples of other girls interested in technology and computing, these peers also play an important role in reducing the effects of stereotype threat — reduced confidence and performance when one is reminded of gender stereotypes, such as "girls are not good at math or technology."

Of course, the flip side is that peer influence can have a negative effect on girls' perceptions and interests if their peers are not interested in or supportive of computing. This can be the case if girls often find themselves in all- or mostly-male environments as this can increase discomfort and activate stereotype threat (Aronson, et al., 1999; Spencer et al., 1999; see page 35 for more information on stereotype threat). In a mixed-methods study of 158 Canadian students, girls indicated in interviews that their interest in computing classes was influenced by social factors like their perceptions of the climate of the computer lab and whether classes were being dominated by boys (Jenson et al., 2003). Similarly, in another study, nearly half (47%) of all girls said that they would feel uncomfortable being the only girl in a group or class (Girl Scout Research Institute, 2010). Finally, in a computer game playing program, researchers found that only four boys reported playing computing games with girls (all reported playing with other boys) while all of the girls reported playing with boys and only infrequently with other girls (Jenson, et al., 2007). While some girls may certainly enjoy playing games with boys, the imbalance here suggests that many girls might not and that boys do not tend to initiate playing these games with girls.

Single-sex education can be influential in capitalizing on the positive aspects and mitigating some of the more negative aspects of peer influences. Research on single-sex education, in general, has often found many benefits for girls, including increased confidence and interest in traditionally male-dominated subjects (Barker & Aspray, 2006). In one of the first in-depth empirical studies on all-female computer science courses in secondary school, Crombie et al. (2002) found that all-female environments can have better outcomes for girls because girls perceive more support from teachers. All-female environments also gave girls more confidence than mixed-sex classes, and the girls were more vocal than in other classes. Girls from all-female courses reported more academic interests in computer science or potential to pursue a computing career (Crombie et al., 2002).

Media and Popular Culture: Computing as masculine and “geeky”

As Susan Bordo explains, we live in an empire of images, of “endless commercials and advertisements we believe we pay no attention to” (2003, p. xiii). This empire of images impacts our ideas and ideals in many arenas, including whom we see as qualified for computing work when we see certain kinds of people doing certain kinds of jobs (Wolkowitz, 2006). Past research has investigated the way in which computing and technology are portrayed in a variety of media texts (e.g., Jenson & Brushwood Rose, 2003; Sanders, 2006). In the late 1990s, Sanders (1998) analyzed computer magazines for educators and found that approximately 75% of people portrayed or mentioned were men. Similarly, Knupfer & Nelson (1998) examined computer advertisements, the Internet, television, and movies and found rampant gender stereotypes about people in technical roles. In what follows, we take a look at some more recent research in this area.

Media representations still largely portray stereotypes but progress has been made in portrayals of other occupations, showcasing the power of media to alter these perceptions. More recent research finds that women are still represented stereotypically in popular culture, such as holding little power or understanding of technology, occupying marginal roles in organizations, and being passive individuals (Cozza, 2011; Jepson & Perl, 2002). Adya & Kaiser (2005) note that there has been some improvement over the years with technology trade journals showing young women in professional roles, but note that young girls do not tend to come into contact with these magazines as often. The most popular teen magazines for girls, such as Seventeen, include very little content showing women in professional, technological careers (Adya & Kaiser, 2005).

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"Don't hear a lot about being [in] tech careers. More — doctors, lawyers. If you knew more about it [you] might want to do it."

teen girl, Orlando, FL (GSRI, 2012)

Additionally, media images often still present the stereotype of computer professionals as geeks without social skills doing boring and solitary jobs (Klawe, 2002). While there have been efforts to reclaim the "geek" label as a kind of cool image (e.g., Best Buy Co.'s Geek Squad, various "girl geek" websites, communities, and events), this too can negatively impact many girls' perceptions of the study of IT and computing (Barker & Aspray, 2006; Cheryan, et al., 2011a). However, some evidence suggests that at least some girls also actively join in efforts to reclaim the geek image (e.g., girl geek dinners, sites like **geekgirls.com**). Additional research suggests that girls of color are less affected by perceptions of "geek culture" in technology and that any such negative perceptions are outweighed by the prestige and high pay they associate with computing careers (Varma, 2007). More research is needed to understand how the geek label actually impacts a diverse range of girls' interest and intentions when it comes to computing.

Interestingly, more progress has been made in portrayals of other occupations. In many television shows, women are now portrayed in powerful positions in previously male-dominated areas such as medicine, law, and forensic science, amongst others (Jepson & Perl, 2002). One survey of 508 U.K. students aged 14-18 found that forensic scientist — an occupation only recently popularized in recent crime dramas such as CSI — was girls' 6th most popular job choice and boys' 8th most popular job choice (Miller & Hayward, 2006). This hints at the power of popular culture to raise awareness and influence youth perceptions about occupations. Interestingly, in this same study, boys' top three choices — webmaster, computer engineer, software engineer — were all computing-related. Computer engineer and software engineer were girls' 15th and 18th choice, respectively.

And, when it comes to computing careers, interesting but complicated developments are on the horizon and worth paying close attention to. Few movies or prime time television shows take place in a technology setting and even fewer have a powerful female lead character (Clayton, et al., 2009). Clayton et al., do highlight one recent positive example of a female in a computing role, Penelope Garcia, from the crime drama *Criminal Minds*. However, while her character is positively portrayed in many ways, her character also tends to reinforce many stereotypes as she is portrayed to be a somewhat "quirky" person, is obsessed with online gaming, wears glasses, dresses in what might be considered somewhat funky or "geeky" attire, and is often referred to as the "tech with glasses." When she is shown actually working with computers, she also is usually shown working alone in a darkened room. An eerily similar pattern emerges in the character of Abby Sciuto, the female character in a computing role in another crime drama, *NCIS*. In some ways, of course, these characters are very positive developments because they are very likable female characters and some girls are likely to identify with them, see themselves represented, and have these aspects of their identities validated. At the same time, it is curious that the two leading female technical characters on prime time television would be portrayed in such similar ways. These patterns are worth watching because if all of the female characters in technical roles end up having these kinds of similar characteristics, this can reinforce certain stereotypes and limit the number and kinds of girls who see themselves in these representations.

The rise of gaming and its influence on girls' participation in computing merits further research. In addition to more traditional media texts, games have become a significant aspect of popular culture and are often children's first introduction to computing kinds of activities. While in the past boys spent more time gaming, recent findings suggest that this divide is narrowing (Hayes, 2008; Dresang et al., 2007). Because of this recent trend, games are also seen by many as a particularly promising way of making computing and computer science classes more relevant for youth and involving them early in actual computing activities (e.g., Hayes, 2008; Hughes, 20008; Kafai et al., 2008; Kelleher, 2008). This potential is complicated, however, by the fact that historically games have been primarily made by men and for male audiences. Much past research has examined the pervasiveness of stereotypical representations and narratives in computer games and these also are still quite rampant in many games (Cassell & Jenkins, 2000; Cooper, 2006; Hayes, 2008 Jenson & Brushwood Rose, 2003). Likewise, many games created for girls reinforce stereotypes about the kinds of things girls are interested in (e.g., Hayes, 2005). Research has shown that it is important to move beyond stereotypes about what kinds of games interest girls versus boys and take a more complex look at how women actually interact with a variety of games and the nuanced reasons that they like or dislike certain aspects of games (e.g., rather than for example, assuming all girls or women do not like violent games) (e.g., Hayes, 2005; Kafai, 2008).

When it comes to potential for fostering interest in computing, evidence also suggests that the games targeted to male audiences more commonly allow users to make programmatic modifications (or "modding") and other kinds of computational interactions, which more directly develop actual computing or programming skills (Kafai; 2008; Hayes, 2008). Also, these features tend to foster more online communities where boys gain more advanced skill interacting and exchanging knowledge more frequently with other players (Hayes, 2008). Nonetheless some of these trends are changing, as girls have begun to start gaming in equal number to boys, and evidence does suggest that gaming can be an engaging way to introduce computing for girls (Denner, 2011; Hayes, 2008, see the Promising Programs section on Gaming, p 58, for more information).

Boys are more likely to say that an interest in gaming is a reason for choosing a computing career. In her survey of 836 high school pre-Calculus and Calculus students in California and Arizona, Carter (2006) found that the top reason boys would choose a CS major was interest in computer games, whereas it was the third most positive influence

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"I thought about being a videogame designer because in English we just had to turn in a project about video games. It seems like fun; you get to put all your ideas into a game you get to create."

teen girl,
Indianapolis, IN
(GSRI, 2012)

*

"Something like a video game designer, I don't think anyone should do. Because video games aren't really good for you."

preteen girl,
Wilmington, DE
(GSRI, 2012)

for girls. Approximately 300 boys chose gaming, whereas only 75 girls did the same. The top reason girls would choose a CS major was a desire to use CS in another field. Colley (2003) found similar results in boys' and girls' selection of gaming as a reason for choosing a technical career. Some initial research, however, does provide support for the fact that programs that use gaming to increase girls computing knowledge and interest in future careers do have positive effects (e.g., Denner, Werner, & Ortiz, 2012; see Section 3, page 58 for more information on some of these programs and their effects). In order to better understand the links between gaming, popular culture representations, and computing education and careers, more research is needed into the actual gaming practices of girls and how they learn computer science concepts through these practices (Denner, 2011).

Summing It Up: Girls' Perceptions, Interest, Confidence, and Career Decisions

"...variation within sex is often greater than variation between the sexes"

In previous sections, we have touched on how a variety of factors influence girls' perceptions, interests, confidence, and career decisions. Here we summarize and highlight the most consistent and well-supported findings. While, in this final section, we do explore girls' perceptions, interests, confidence and career decisions, as well as how these sometimes differ from boys, it is important to remember that girls and boys do not develop these beliefs and perceptions in a vacuum. These beliefs are influenced by the social and structural factors discussed above. Furthermore, because many studies focus on differences between boys and girls, the significant similarities are often glossed over. For instance, Hyde and Linn (2006) note how girls and boys are overwhelmingly more similar than different; they also examine how cognitive or biological differences are not at work in preventing girls from participating in IT (Hyde & Linn, 2006). A number of recent studies have found that with similar training and experience, girls and boys perform in computer technology at comparable levels, showing no innate reason boys would be better at technology (Barron, 2004; Bruckman et al., 2002; Voyles et al., 2007). It is also important to remember, but is rarely discussed, that while girls and boys sometimes differ when it comes to their perceptions, interests, and career decisions, variation within sex is often greater than variation between the sexes.

Girls' Perceptions of and Interest in Computing

Girls (and often boys) still have limited knowledge or inaccurate perceptions about what computing careers involve. As we have touched on earlier, myriad past and recent studies have found that girls either have very limited knowledge or inaccurate perceptions of what IT professionals do. Generally, girls perceive IT careers as having little or no interaction with others and that IT workers are obsessed with computers (e.g., Anderson, et al., 2008; Grant & Payton, 2008; Howe et al., 2007; Lasen, 2010; Papastergiou, 2008; Teague, 2002). In a survey administered to more than 800 calculus and pre-calculus students in nine California and Arizona high schools, 80% of respondents, both male and female, had no idea what CS majors learn (Carter, 2006). Those students who thought they had an idea thought CS majors learn programming. Only 2% of the high school students surveyed "had a reasonably good grasp of what the field of Computer Science entailed" (p. 29). Another study of 320 junior girls in top-level math classes found that a lack of knowledge about computer science and computing careers were top reasons for not choosing a CS major (Olivieri, 2005).

Similarly, in a survey in a University of Minnesota summer computing camp targeting girls, African American students, and Hispanic students, Cannon and colleagues (2007) asked, "What might a computer scientist do in his or her spare time?" (p. 15). Seventy-two percent of the students believed that the computer scientist would remain at a computer while either working or playing video games. Descriptions and drawings of computer scientists with glasses and lab coats further revealed the students' perceptions. When asked if they would be willing to work at a job where they would need to use a computer for at least one hour a day, the majority said yes (75%), but when asked if they would be willing to work at a job requiring six hours at a computer the number dropped substantially, but with, perhaps, a surprising gender breakdown — 44% of the girls remained interested but only 9% of the boys remained interested. The most common explanation was that it would be "boring". The gender breakdown for this response is a bit surprising and merits further investigation, especially as this was a camp that had a high percentage of African American and Hispanic students.

"When I think about careers and computer programming, I think of people like my dad. Always sitting at the laptops, looking at all these different websites, just working a lot."

young girl, Austin, TX (GSRI, 2012)

Girls (and boys) still perceive computing to be a largely masculine field. In a study where 6th and 8th graders were asked to close their eyes and portray someone who "really knows a lot about computers and likes to use them" in either pictures or words, the majority of representations from both boys and girls were of males, and they often included stereotypical "geeky" features, like the wearing of glasses (Mercier et al., 2006). Additional studies indicate that male and female students continue to see computer science as a primarily "male" field and to make their career choices accordingly. In Moorman & Johnson's (2003) study, only 16.8% of female students were interested in pursuing an undergraduate degree in CS compared to 48.2% of their male counterparts. In addition, 55% of students of both genders indicated that males are more naturally inclined towards math and CS. Only 6% indicated that females are more naturally inclined, while 39% indicated gender equality in ability.

In another study, 508 U.K. students aged 14-18 were surveyed for their perceptions regarding 23 occupations. In general, girls perceived occupations as being more gender-segregated than did males, but boys tended to see occupations as more gender-stereotyped than girls. Both girls and boys preferred jobs that they saw as stereotypically gender-appropriate and dominated by their own sex. Interestingly, however, for girls, this connection decreased with age, but for boys it remained consistent across age groups (Miller & Hayward, 2006).

Interest varies among girls of different ethnicities and among girls already interested in science. A recent survey of 852 girls of diverse ethnicities also sheds additional light on girls' interest in pursuing computing (GSRI, 2012). The researchers distinguished results from girls who currently are interested and engaged in STEM activities ("STEM girls") versus girls who say that they are not interested or engaged in STEM ("Non-STEM girls"). When asked, "How interested are you in Computer Science/ Information Technology (computer programming, networking, security, computer support, etc), 41% of all girls expressed interest, and 51% of girls who were already interested in

STEM expressed interest. African American and Hispanic girls expressed greater interest in CS and IT than White girls (47%, 47%, and 36%, respectively).

Interest in some aspects of STEM and computing was also higher for African American and Hispanic girls. Consider the following results:

% WHO AGREE	WHITE	AFRICAN AMERICAN	HISPANIC
I like to understand how things work.	75	82	83
I think it would be fun to create an iPhone app or design a computer/video game.	55	67	68
I like building things or putting things together.	56	58	67
I like to understand how things are built.**	57	57	64
I like puzzles and and solving problems.**	77	81	80
I like doing hands-on science projects.**	70	74	73

***No statistical significance in these ethnic differences.*

Girl Scout Research Institute (GSRI), Generation STEM report, 2012. Reprinted with permission of GSRI.

Similarly, a longitudinal study of 1,482 adolescents also found that African American girls were more likely than White girls to consider IT careers (Zarrett et al., 2006). Interestingly, they also found that African American girls with plans to attain higher levels of education had less interest in IT careers than African American girls with plans to attain lower levels of education.

Interest in STEM or computing does not necessarily translate into interest in a career in these fields.

- Eighty-one percent of girls currently interested in STEM expressed interest in pursuing a career in engineering, physical/life science, math, computer science/information technology, or software development. However, only 13% of STEM girls said that this was their *first* choice.

- In contrast, two-thirds of STEM girls expressed interest in medicine/healthcare as a career (careers such as a doctor, veterinarian, nurse, pharmacist, dentist) and approximately one-third listed this as their number one career choice. The top four ranked careers of interest were medicine/healthcare (65%), arts/design (64%), social science (60%), and entertainment (59%).

* When asked specifically if they were interested in a career in computer science/information technology (networking, programming, security, desktop support, audio/visual support, etc.), 11% of non-STEM girls reported an interest. This number only increased to 27% for girls already interested in STEM. Only protective services, manufacturing/production, armed forces, and construction/installation/maintenance/repair were ranked lower.

* When asked for their first choice, only .8% (eight-tenths of one percent) of all girls and only 1% of STEM girls answered computer science/IT.

% GIRLS INTERESTED IN PURSUING COMPUTING VS OTHER SELECTED CAREERS	STEM GIRLS	NON-STEM GIRLS
Medicine/Healthcare	65	32
Arts/Design	64	70
Social Science	60	48
Entertainment	59	67
Communications/Media**	58	59
Physical/Life Sciences	57	15
Community/Social Services**	57	51
Education*	44	38
Business/Finance	43	29
Law	41	30
Engineering	32	3
Math	31	5
Architecture	30	16
Stay-at-home mom**	30	34
Computer Science/Information Technology	27	11
Software Development	25	13
Protective Services	22	15
Manufacturing/Production**	15	13
Armed Forces	14	8
Construction/Installation/Maintenance/Repair	8	3

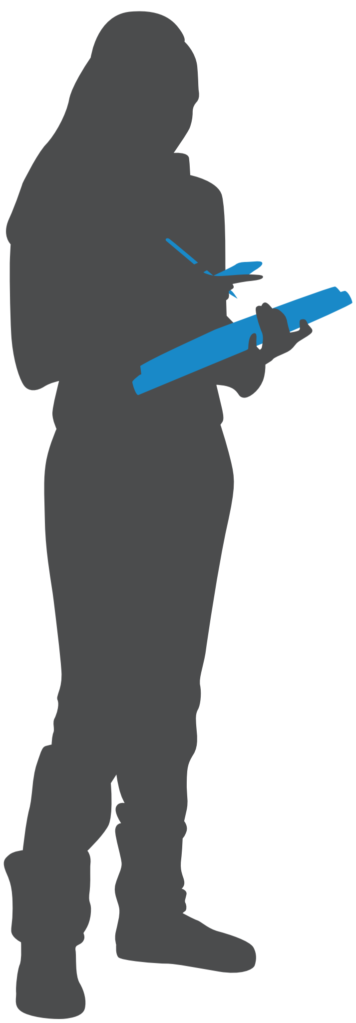
**Significant only at 90% confidence. **Not statistically significant. All others significant at 95% confidence.*

Girl Scout Research Institute (GSRI), Generation STEM report, 2012. Reprinted with permission of GSRI.

Since one of the strongest direct predictors of girls' interest in computing classes is the extent to which they see value and relevance in computing (e.g., Denner, 2011), changing girls' lack of knowledge and perceptions is vital for increasing these levels of interest. However, as noted above, increased interest does not always translate to intention to persist. This seems partly due to competing interests in other fields. It may also be because current research is unable to distinguish between different kinds and levels of interest and the resulting effects of these for girls' decision-making. Future research would do well to tease out what is meant by interest and the differences in kind and degree of interest, as well as helping advance understanding in how these relate to confidence, experience, and reasons for choosing a computing career. We now take a closer look at some of the research related to these last three factors: confidence, experience, and reasons for choosing a career.

Confidence

Since the introduction of computing curricula in the 1990s, boys have expressed higher levels of confidence with computers and technology (AAUW, 2000; Barker & Aspray, 2006; Moorman & Johnson, 2003). A number of studies have shown that confidence in computing ability and encouragement from influential others are two important factors in predicting girls' intentions to pursue a computing career (e.g., Barron, 2004; Zarrett et al., 2005). The exact interactions between experience, confidence, interest, and plans to persist in computing, however, are not well understood. This is, in part, because of differences in the kinds of studies conducted: most studies still focus more on confidence in computer usage as opposed to confidence in computing itself and studies differ in terms of the age, geographical location, race/ethnicity, social class, and other demographic characteristics of the children studied. More research is needed to tease out these variations in findings and also to better understand how these factors interact in terms of intersections of race, gender, class, and sexuality.



Girls express less confidence and rate their ability lower than boys, even when actual achievement levels are similar. This continues to be one of the most consistent findings when it comes to the relationship between gender, confidence, and computing. For example, in one study, participants were asked to rate their computing ability against other students' computing ability. Sixty-five percent of male students claimed to be more advanced than their female classmates, and 52% claimed to be more advanced than other males in their classes. Comparatively, only 19% of females claimed to be more advanced than their male classmates, and 37% claimed to be more advanced than other females (Morman & Johnson, 2003).

Similarly, in an experimental study, participants' estimations of their own competence were lower when they watched a male subject complete a computing task than when they watched a female subject complete the same task (Koch et al., 2008; Sieverding & Koch, 2009). These, and similar findings, suggest that it is particularly important to limit the "posturing" of male students in classrooms, as this can be particularly damaging to the confidence levels of female students, especially those with less prior experience (Barker & Garvin-Doxas, 2004; Sieverding & Koch, 2009)

Experience definitely seems to boost girls' attitudes toward and confidence in computing (Barron, 2004; Cohoon & Aspray, 2006; Guzdial et al. in press). Programming achievement is predicted by programming experience rather than gender; in other words, when looking at students with equal levels of programming experience, gender differences in achievement disappeared (Barron et al., 2010; Bruckman et al., 2001). However, girls often still assess their own abilities lower than do boys with similar levels of experience (Crombie, 2003; Guzdial, et al., in press). In one particularly interesting study, albeit with undergraduate students, Beyer and colleagues (2002) found that female CS majors had less computer confidence than did male non-majors.

Stereotype Threat: "Great job! You're living proof that girls really do have a technical mind!"

Even when said in jest, these kinds of comments (or more subtle comments) can invoke stereotype threat – the fear or anxiety that our actions will confirm negative stereotypes about our "group" or about ourselves as members of a group. *A wealth of research has illustrated that these fears and anxieties drastically reduce feelings of competence and trust, and can negatively affect performance, confidence, and risk-taking behavior (Aronson et al., 1999; Spencer et al., 1999). Recognizing stereotype threat is important; otherwise educators, peers, parents, and others might incorrectly assume that lack of confidence or reduced performance are the result of personal characteristics of girls themselves. This will leave the conditions that create stereotype threat unaddressed, ensuring that these girls are not able to live up to their full potential and most likely will leave or never choose to pursue computing.*

Recognizing Stereotype Threat

Research on Stereotype Threat

* White male engineering students get lower-than-usual test grades when told in advance that Asian students typically score higher than any other group on math tests (Aronson et al., 1999).

* Other experiments have shown that African American students underachieve on academic tests when told racial stereotypes about intelligence prior to testing (Steele et al., 1995).

* Women underperform on math tests when gender is called to their attention (Spencer et al., 1999).

Men and women tend to have different narratives about how they came to be in a computing career. Men tend to perceive or describe having made decisions very early or "being born" to pursue their careers in high-tech. Women, however, describe having come by their careers through luck, chance, or serendipitous events, even when their career paths had been similar to those of men. These differences may stem from male and female differences in levels of confidence, as well as related effects of stereotype threat. This discrepancy is important to keep in mind and perhaps to challenge because if boys are more prevalent in computing environments, these kinds of narratives might be more prevalent, too. This can give girls or women the impression that to be successful in a computing career you have to have been born into it or have some kind of innate ability (AAUW, 2000).

Encouragement goes a long way toward mitigating differences in levels of self-confidence and perceived ability. Interestingly, a study of 1,434 undergraduate students found that encouragement to persist was the driving factor behind female students' likelihood to choose a computing major or career — more so than their perceptions of or confidence in their ability. This was also true for Black and Hispanic students (Guzdial, et al., in press). As noted in previous sections of this report, the importance of encouragement from parents, teachers, and other influencers is a very consistent finding across studies and is promising news for interventions aimed at increasing girls' and women's participation, since encouragement is a relatively simple strategy that most people can readily implement.

Career Decisions

Some differences exist in girls' and boys' reasons for choosing a career, but the similarities are also striking. Interestingly, what is often lost in the search for differences between boys and girls is the fact that many similarities exist between male and female students' reasons for choosing a computing major or career. In a survey of 836 students in calculus and pre-calculus classes in nine California and Arizona schools, Carter (2006) found that the top reason boys chose a CS major was interest in computer games, but the top reason girls chose a CS major was desire to use CS in another field. She also found, however, that the top reasons for not choosing a CS major for both genders were lack of desire to sit in front of a computer all day and already having chosen another major. Future salary was not a significant influence on choice to study CS for either boys or girls.

"...what is often lost in the search for differences between boys and girls is the fact that many similarities exist between male and female students' reasons for choosing a computing major or career."

Another survey of 1,434 introductory computer science students (Guzdial et al., in press) also found similarities and some differences for a diverse range of students' (31% female and 69% male; 59% White, 15% Asian, 15% Black, 5% Hispanic, less than 1% Native American, and 5% Multiracial) reasons for choosing a CS major/minor and career.

* The three most important reasons for choosing a CS major or minor are the same for both males and females: 1) "I enjoy working with computers," 2) "Computing offers broad and diverse opportunities," and 3) "CS provides good financial opportunities after" (Figure 1).

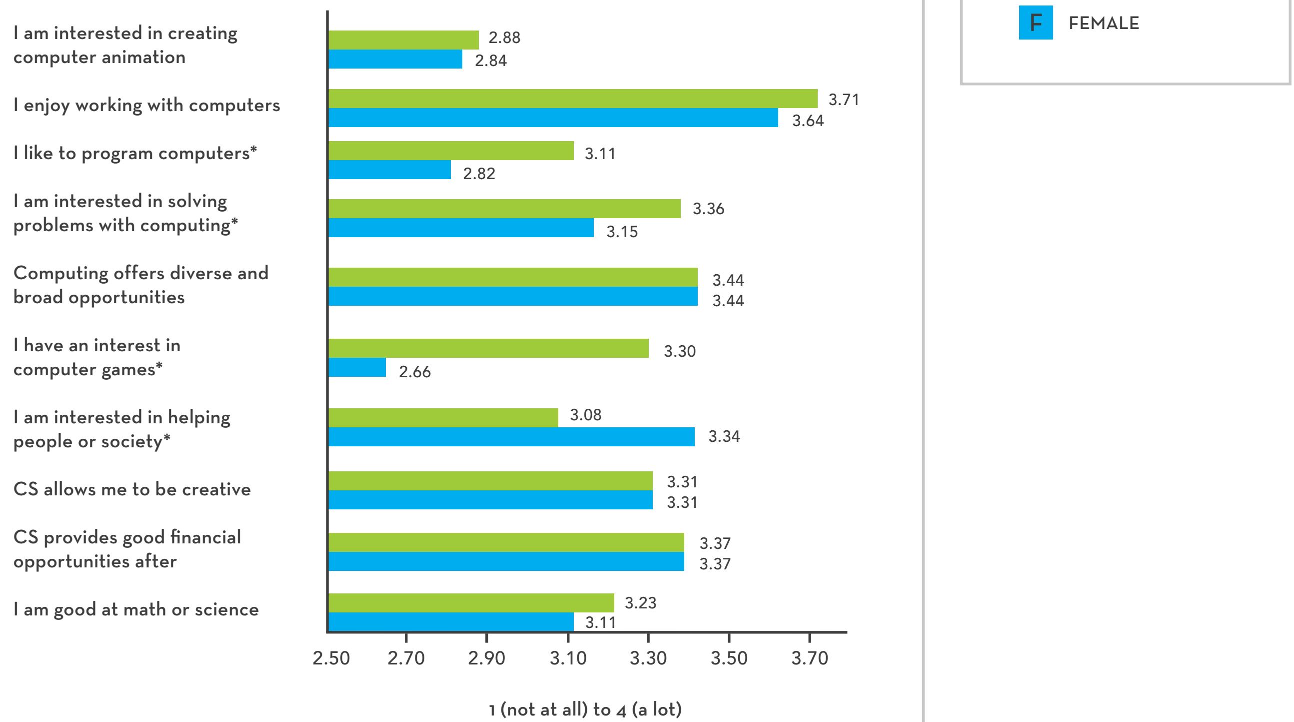
* Female respondents were significantly more likely than male respondents to say that they chose a computing major because of their "interest in helping people or society" (Figure 1).

* Male respondents were significantly more likely than female respondents to cite the following as reasons for choosing a computer major: 1)"interest in computer games," 2) "interest in solving problems with computing," and 3) "liking to program computers" (Figure 1).

* African American respondents were significantly more likely than White respondents to say that “interest in helping people or society” was a reason for choosing a computing major/minor, while Asian and African American respondents were significantly more likely than White respondents (and multiracial respondents) to report “interest in creating computer animation/movies” as a reason for choosing a computing major/minor.

FIGURE 1

REASONS FOR CHOOSING A COMPUTING MAJOR, BY SEX



**Statistically significant (p < .05)*

Guzdial et al., in press. Reprinted with authors' permission.

When exploring students' reasons for choosing a computing career, the researchers found the following:

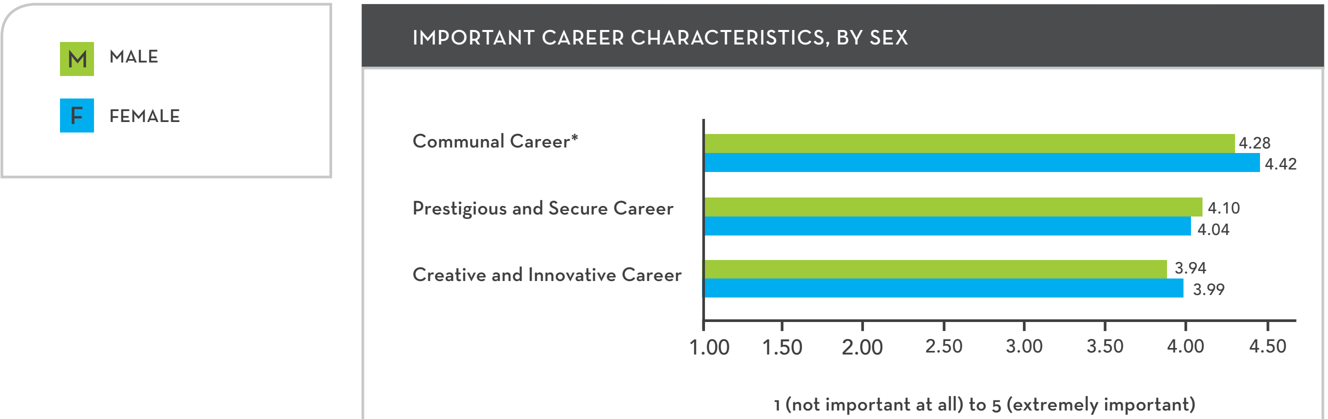
* Female students were significantly more likely than male students to place importance on communal career characteristics, such as “being able to spend time with your family,” “having the power to do good,” or “doing work that makes a difference.” (Figure 2)

* But, notably, male students also placed a high value on these characteristics—higher than either of the other two categories: having a prestigious and secure career or a creative and innovative career. At the end of the day, males and females actually both ranked communal characteristics as the most important characteristics of their desired job. (Figure 2)

***** Asian, African American, and Hispanic respondents also were significantly more likely than White respondents to place importance on "having a creative and innovative career" and on "achieving job security and prestige" in their profession. (Figure 3)

FIGURE 2

IMPORTANT CAREER CHARACTERISTICS, BY SEX

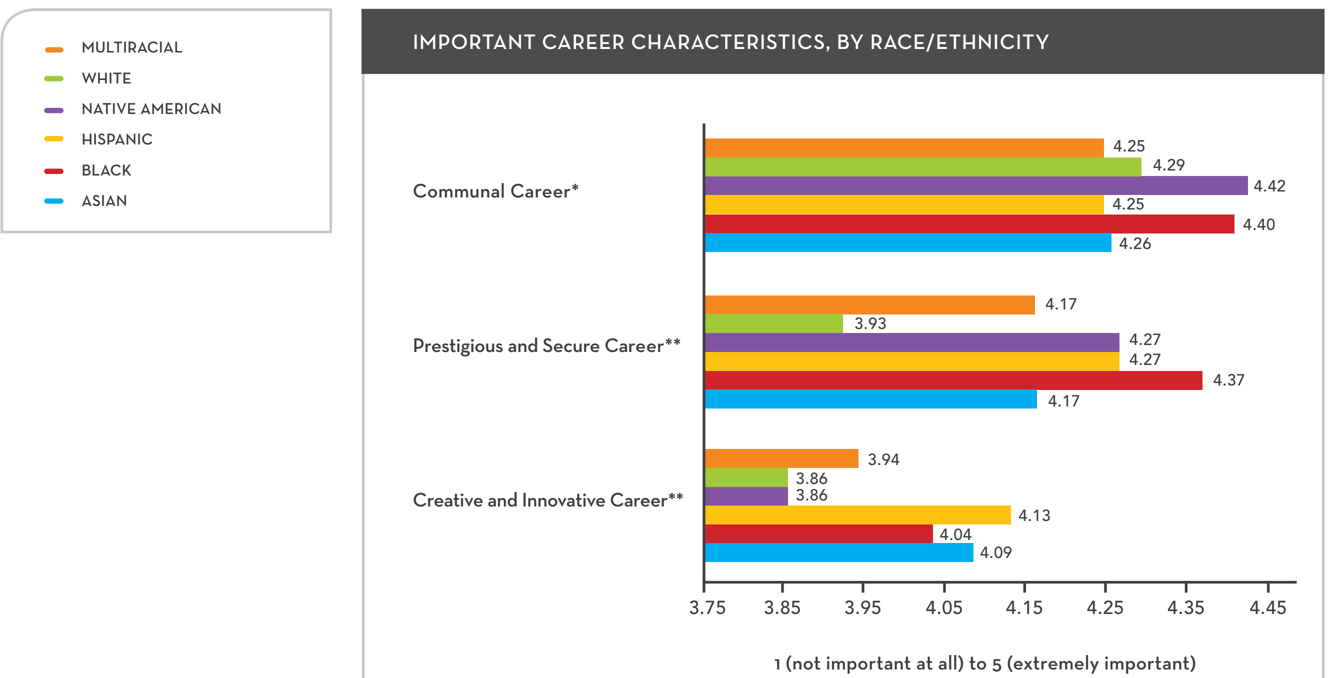


**Statistically significant (p < .05)*

Guzdial et al., in press. Reprinted with authors' permission.

FIGURE 3

IMPORTANT CAREER CHARACTERISTICS, BY RACE/ETHNICITY



**Statistically significant (p < .05) **Statistically significant (p < .01)*

Guzdial et al., in press. Reprinted with authors' permission.

In this section, we have looked at the key barriers to increasing girls' participation in a number of contexts. We now turn to look at promising practices for addressing these barriers.

Section 3

Addressing the Barriers: What can we do to change the current state of affairs?

Section Snapshot

This section is divided into two parts: 1) Recommendations and links to practical resources for implementing change, organized by change agent, and 2) A glance at promising programs that are implementing these kinds of changes.

Recommendations and Links to Practical Resources

- **What can anyone looking to make change do?**
- **What can parents and families do?**
- **What can post-secondary computer science and teacher education faculty do?**
- **What can social science researchers do?**
- **What can legislators and policymakers do?**
- **What can formal and informal education do?**
  - What can computing or computer science educators do? What can other educators do?
  - What can school counselors do?
  - What can administrators and other school district personnel do?

A Quick Glance at Promising Programs

Recommendations and Links to Practical Resources

After looking at the research on barriers to girls' participation, it is clear that there is no single, easy answer to increasing girls' participation in computing. Reform requires multiple kinds of change agents taking a multi-faceted approach. The following model aims to depict the keys areas where change is needed and who can effect this change.

The outer ring depicts all of the people who need to be involved for effective, systemic change to occur. The outer shapes surrounding the center indicate the key areas where change is needed in order to make existing conditions around gender and computing more inclusive for girls and youth of color. Change in these areas will ultimately also affect girls' perceptions, interests, confidence, and reasons for choosing a career.

In the next few sections, we offer tips or recommendations from existing research, as well as links to practical resources for implementing these recommendations. These recommendations and resources are categorized by the people or organizations most likely to be able to implement them. Some of these tips are logical solutions arising out of the research on known barriers discussed in Section 2, while others also have evaluative evidence of success. In the case of the latter, we note what these successes have been.

In the final section, we offer a glimpse of promising programs that simultaneously address multiple barriers and have positive evaluative evidence.

What Can Anyone Looking to Make Change Do?

Since there is some overlap in some of these recommendations, we begin with a set of recommendations that almost anyone looking to make change might be able to do.

* **Talk to key influencers in girls' lives—parents, teachers, school counselors—about the need for increasing diverse participation in computing and why girls should consider a technical career.** Use the bullet points on pages 2–3 of this report to make the case for why increasing girls' participation is important. Additional talking points for the importance of computing education are available at www.ncwit.org/schools. Talking points for why girls should consider a career in computing are also available at www.ncwit.org/youngwomen.

* **Make the case for improving computing education to educators and to local, state, and national policymakers and curriculum decision-makers.** In making this case, be sure to distinguish between computer literacy and computer science. Also, visit www.ncwit.org/edjobsmap for an interactive map that provides local, state, and national data on the number of computing graduates versus the number of computing jobs. Resources on this website also show how others have used this data.

* **Talk with girls you know about why they should consider a computing career.** Be sure to point out the ways that computing can be used in a variety of fields to solve important problems. Highlight that these jobs are well-paying and likely to be quite plentiful. Visit www.ncwit.org/youngwomen and the Dot Diva website at www.dotdiva.org for additional tips on talking with girls about these careers and for resources showing how computing can be linked to relevant jobs.

* **Talk with girls and others about unconscious biases like stereotype threat, its effects, and what can be done about it.** Make girls aware of this phenomenon; recognizing it is the first step to overcoming it. Also remind girls that intelligence and technical ability are not innate but that they are like muscles that can be developed over time. A number of important interventions for reducing stereotype threat have been found to be successful. For more information on these strategies or on stereotype threat in general, see www.ncwit.org/stereotypethreat and www.reducingstereotypethreat.org.

* **Provide ongoing encouragement. Never underestimate the power of this simple effort.** Encouragement is important for all students, but the research reviewed here shows that it is one of the most influential factors in girls' decisions to pursue computing education and careers, even more important than self-assessments of ability. As Guzdial (in press) observes, this is good news for intervention efforts because changing students' self-perception of ability is challenging, but encouraging them is not.

- **Do NOT mistake prior experience for ability.** It is sometimes easy to make quick assessments about students' or children's "inherent" talent for computing tasks. However, these are often based on the fact that some children have simply had more experience with computing than others. Confusing prior experience with ability will ultimately lead to inaccurate perceptions of girls' abilities as, to date, they typically have less early exposure to these activities than boys. This is particularly true for girls of color and girls who come from underresourced areas (Cunningham, 2011; Margolis et al., 2008).

- **Have informal conversations with girls (and others) about media and popular culture representations of technology and computing.** As appropriate, strike up informal conversations with youth and others about media portrayals regarding technology and technology professionals. Even small comments when running across these representations can "interrupt" the moment and help people question these representations.

What Can Parents and Families Do?

- **Provide girls with early technology and computing experiences.** As discussed in Section 2, quite a bit of research shows the importance of early exposure to technology and computing, and familial encouragement to pursue these interests (e.g., Guzdial, in press). Encourage your daughters or the young women in your lives to take computing classes. Also look for extracurricular computing opportunities in your community or beyond (see Promising Programs section on page 54). Be sure to talk about how computing is relevant in a number of different areas, particularly as it relates to things the young women you know may be interested in.

- **Provide role models.** Look for opportunities where your children can see girls and women participating and successful in technology. See www.dotdiva.org and www.ncwit.org/heroes for inspiring stories about what women have accomplished with technology. Likewise, visit the site for the NCWIT Aspirations Award winners (www.ncwit.org/award) to see exciting things adolescent girls are doing with computing. Also, consider innovative ways you might function as a role model, even if you don't currently consider yourself "technical." For example, one program offered a mother-daughter elementary school club to help build girls' and mothers' computing expertise. The club increased competency and self-esteem for both mothers and daughters and allowed mothers to better become female computing role models (Moorman & Johnson, 2003).

- **Have discussions about media representations and unconscious biases with your children or children you know.** When watching television shows, reading magazines, or coming across advertisements related to technology, strike up informal conversations with children about the kinds of representations they are seeing. Ask for their opinions about these representations and offer your own. Even small comments when running across these representations can "interrupt" the moment and help people question these representations.

* **Talk with your children or children you know, particularly girls, about why they should consider computing careers.** Remember that girls often know very little about or have significant misconceptions about technical careers. Make them aware of the benefits of these careers. Talking points for having these conversations with young women are available at www.ncwit.org/youngwomen.

* **Talk with teachers, counselors, and school personnel about the need for computing education, especially early education**. In making this case, be sure to distinguish between computer literacy and computer science. Talking points for making this argument are available at www.ncwit.org/schools. Also, visit www.ncwit.org/edjobsmap for an interactive map that provides local, state, and national data on the number of computing graduates versus the number of computing jobs available, which is also particularly helpful when arguing for computing education.

What Can Post-secondary Computer Science and Teacher Education Faculty Do?

* **Advocate for CS certification and the adoption of CS curriculum standards.** Teacher education faculty can educate others about the need for training highly-qualified computer science teachers and advocating for the adoption of state curriculum standards in computer science. This is important for making CS an established part of the curriculum. For more information on creating a CS endorsement, see the teacher certification section on the Computer Science Teachers Association (CSTA) website at www.csta.acm.org. For more information on CS curriculum standards, see the curriculum section of the CSTA website.

* **Advocate for or host teacher professional development workshops for a range of teachers.** Both computer science and teacher education faculty can offer professional development for teachers who wish to learn about computing and how they might incorporate computing lessons into their classrooms. These workshops are useful for math, science, and CS teachers but also can be useful for art, music, language arts, social science, and other kinds of teachers who may wish to incorporate computing lessons into their classrooms. Promising programs like Georgia Computes! (http://gacomputes.cc.gatech.edu/) and Exploring Computer Science (www.exploringcs.org) provide comprehensive teacher professional development. Likewise, Agentsheets (www.agentsheets.com), Globaloria (www.globaloria.org), and COMPUGIRLS (http://sst.clas.asu.edu/about/compugirls) train teachers to teach computing and technology classes in school and/or after school. The Tapestry Workshop Series (http://www.cs.virginia.edu/tapestry) also partners with local universities to provide computer science teachers with strategies for actively recruiting girls into their classes and for teaching computing in engaging ways. Find out how you can partner with these kinds of programs or use lessons learned from them to start similar professional development on your campus.

"Mostly, I...talked to girls individually in the hallway. I also put up posters. Talking to girls individually really helped. Several said they would give computing a try, and several actually joined my robotics team!"

—computing teacher participating in Tapestry workshop

- **Mentor young girls interested in computing; multi-level mentoring has been shown to be particularly effective.** Having many mentors and individuals supporting and encouraging participation can help girls increase interest in computing. Programs such as the STARS Alliance (http://www.starsalliance.org/) provide mentoring across stages; for example, professors mentor graduate or under-graduate students who mentor "near peer" high school girls (Dahlberg et al., 2011). A variety of programs using this multi-level mentoring model have produced positive results in changing girls' perceptions about computing; likewise, the college students serving as mentors also describe these programs as helping them feel empowered (Lang et al., 2010; Marcu,2010). Also, remember that mentoring does not only have to take place in person. Telementoring or e-mentoring can be an effective method to bring mentors or role models to girls who may not have any locally (Cozza, 2011). See www.mentornet.net for an example of one such program.

- **Host or offer K–12 computing outreach programs using campus facilities and resources.** A variety of informal or summer programs for increasing girls' participation have been implemented at university and college campuses (See Promising Programs section on page 54). Hosting these events on college campuses provides access to resources that local schools do not always have and also allows many girls (and other students) to experience a college campus for the first time.

- **Ensure that your own department employs inclusive practices that will retain young women who do decide to enroll.** It won't help to recruit girls into higher education computing programs if they end up wanting to leave. Be sure that your department has created an inclusive and supportive culture and employs inclusive pedagogies in the computing classroom. See www.ncwit.org/resources for promising practices in higher education computing. For a comprehensive guide to implementing these practices in higher education see www.ncwit.org/retainingworkbook.

What Can Social Science Researchers Do?

- **Conduct research on girls and IT.** Help bring more girls' and women's voices and experiences into research conversations in your discipline. Use this report as a call for your or your students' research projects, focusing on areas where we offer more tentative claims or suggest further research, like the uncertainties around parents' technical expertise, the influence of peers, or the role of gaming in CS pedagogy. See the Conclusion and Future Research section on page 62 for other areas where future research is needed.

- **Expand research beyond sex and gender as mere demographic categories.** Initiate research that focuses more on the social construction of gender, and how gender organizes occupations, fields, disciplines, and so forth.

* **Expand research to consider intersectionality and the role race, class, disability, and sexual orientation play in who is able to participate in computing.** Beyond simply focusing on gender, consider the importance of intersectional research and programs that explore multiple intersections of youth's identities for computing pedagogy (e.g., race, class, gender, and sexuality). Diversity of voices and experiences will help not only in the production of richer research but also a richer U.S. computing work force.

* **Use your and others' research to advocate for change.** Translate your research into accessible findings and use these to help support and encourage campus programming for increasing diversity in computer science and IT courses, clubs, and other STEM-related groups. Consider using easily digestible "tidbits" in appropriate campus newsletters or similar venues.

* **Be on the lookout for your own biases.** If you also are a teacher or educator, avoid perpetuating biases showcased in this report and those reported by other researchers, such as confusing prior experience with innate ability, treating information technology as a masculine field (AAUW, 2000; Barker & Aspray, 2006; Clark Blickenstaff, 2005), or equating students' confidence with future success in CS (Barker & Garvin-Doxas, 2004; Margolis et al., 2008).

What Can Legislators and Educational Policymakers Do?

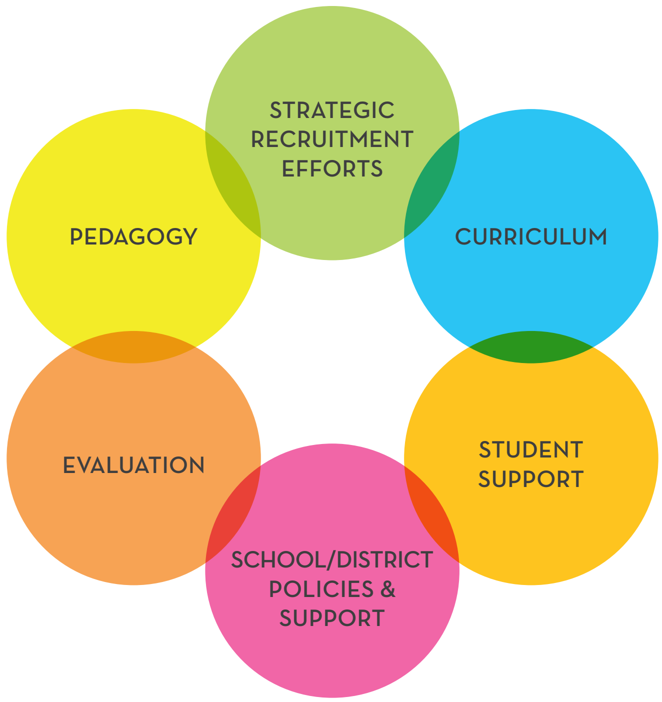
* **Make the case for improving computing education and make sure that this is an important component of educational policies.** To help make this case, visit www.ncwit.org/edjobsmap for an interactive map that provides local, state, and national data on the number of computing graduates versus the number of computing jobs. These data also are presented by congressional district, specifically for state and national legislators. In making this case, be sure to distinguish between computer literacy and computer science, ensuring that policies encourage practices that involve youth in creating not just using technology. Also see the Computing in the Core website (http://www.computinginthecore.org/) for more information on how to advocate for policy around computing education.

* **Adopt CS teacher certification standards and CS curriculum standards.** In making this case, be sure to distinguish between computer literacy and computer science. Visit the Computer Science Teachers Association (CSTA) website at www.csta.acm.org for more information on CS endorsements for teachers and for existing standards and efforts at adoption.

* **Allow CS courses to count for math/science graduation requirements and support moving CS out of elective-only territories in education.** This simple change would help establish computing courses as core curriculum courses and would make it easier and more valuable for students to enroll in these courses.

What Can Formal and Informal Education Do?

Formal and informal education have a crucial role to play in addressing the barriers girls are facing in computing. Of course, reform in these contexts is particularly complex and involves multiple people working on multiple levels. The following diagram illustrates the key areas where reform in education is needed. All of these areas apply to formal education, while only some may apply to specific informal education contexts. You can use this model to identify the areas most relevant for your particular context and to assess which of these areas need the most work.



Making curriculum relevant and employing inclusive pedagogies consistent with sound learning theory, such as hands-on activities, collaborative work, and project-based learning, are important. These reforms, of course, are not enough and cannot be made in isolation or without the support of other parts of the system. Active, targeted recruiting efforts are needed to ensure that girls know about the creative, relevant aspects of computing classes and are encouraged to enroll in them. Administrators and other school district personnel can ensure that school or district policies do not inadvertently discourage students from enrolling in these courses and that teachers have the support and resources necessary to improve curricula and pedagogy. Administrators should also evaluate courses and keep track of gendered enrollment patterns in computing courses. Schools also can offer support for underrepresented students, such as girls' computing clubs or after-school programs. Making sure counselors know how to accurately advise girls and boys regarding computing courses and careers is also an important part of student support.

In what follows, we provide more detail on recommendations in these different areas and links to practical resources for implementing these recommendations.

That's Right — you don't have to be a computing or computer science teacher to help make change!

The following recommendations focus on what both computing teachers and teachers of other subjects can do. *In particular, we make recommendations for recruiting students, improving curricula and pedagogy, and helping to evaluate enrollment and effectiveness of courses. Actions that are especially for teachers of other subjects — as well as other school personnel, such as school librarians — have an icon like this next to them.*

But I'm not a computer science teacher.

Recruitment

* **Don't wait for them to come to you! Actively recruit students into computing and CS courses.** Personally invite girls who might be interested but might not think of enrolling in these courses (Barker et al., 2006; Goode, 2007, 2008). Use "social group recruitment" strategies (Goode, 2008) where you recruit groups of girls into classes so that they are not alone. Recruit from female sports teams and/or classes with higher percentages of girls (e.g. math, language arts, graphic arts, music, journalism/media). When possible, connect computing to their interests in these other classes. This approach has significantly increased female enrollment in CS courses in a number of schools (Goode, 2008). Learn more about active recruiting strategies by attending a Tapestry Workshop (www.cs.virginia.edu/tapestry) for computing teachers.

Encourage girls to take computing courses by talking about computing or CS as an "enabler" subject. When describing these courses to girls, highlight how computing can enable them to solve important problems or help make other products and services better. Research with girls (and with women reflecting on their secondary school experiences) has shown that these real-world and problem-based topics improve girls' perceptions and interest in these courses (Barker et al., 2006; Lasen, 2010; Teague, 2002). See www.ncwit.org/youngwomen, the Dot Diva Website (www.dotdiva.org), and the Bits and Bytes NSF newsletter (www.nsf.gov/cise/csbytes/) for resources to help make these connections.

Curriculum

- **Make computing curriculum relevant, connect to students' prior interests, and showcase how computing can be used to solve important problems.** It is, of course, not enough to make these connections during recruitment. Showing how computing can improve people's lives and solve social problems throughout the curriculum is important for increasing both girls' and boys' interests (e.g., Barker et al., 2006; Goode, 2007; Margolis et al., 2008; Vekiri, 2010). These connections also help to correct misconceptions many students have about computing careers as isolated, machine-focused work (Grant & Payton, 2002; Lasen, 2010; Papastergiou, 2008). See www.ncwit.org/resources for engaging ways to teach computing.

- **Use active, hands-on learning activities.** These kinds of activities are important for all students, but are especially important for girls when they are a minority in a classroom environment. These activities help retain girls' interest and make it relevant for them, when they might otherwise be wary of classes dominated by boys. Allowing students to choose their own projects also tends to increase interest (Marcu et al., 2010; Weber & Custer, 2005). Active problem solving increases students' technological fluency (Cunningham, 2011; Denner, 2011), so it is important for both boys and girls. See www.ncwit.org/resources for engaging ways to teach computing.

- **Focus on fluency—the ability to understand concepts that transfer across multiple situations.** Sometimes too much emphasis is placed merely on competence in rote tasks, but this results in students running into the same problems again and again because they don't understand the underlying concepts (Cunningham, 2011). Focusing on fluency is also particularly important for girls who often come to these courses with less prior experience in computing. Evidence also suggests that a focus on depth is rewarding and fosters success in later science courses (Crombie et al., 2002; Schwartz et al., 2009). More research is needed, however, to understand exactly how this plays out in computing.

"I recruited the girls by volunteering to be the 'restroom monitor' in between classes. I talked to the girls, told them about my class, and signed them up."

—computing teacher participating in Tapestry workshop

- **Provide role models.** Emphasize the contribution of women in CS and IT (Papastergiou, 2008). Partnering with industry professionals, such as bringing in guest speakers to girls' classrooms or offering women's success biographies, helps to challenge stereotypes about computing work and who is supposed to do it (Jepson & Perl, 2002; Lang, et al., 2010). See www.ncwit.org/outreach for a lesson plan and other tools you can use to help guest speakers present to your classes.

  Telementoring is also an effective method to bring mentors or role models to girls when there is an absence of local mentors (Cozza, 2011). See www.mentornet.net for one such program. Remember that multiple role models are helpful to students, so having female mentors is incredibly helpful but girls also need diverse mentors and they need to see the mentor as similar to them and relatable (Cheryan & Plaut, 2010; Cheryan et al., 2011b).

* **Make explicit that the activities students are doing in class can lead to computing careers.** Middle school students' perceptions of technology and science careers are often incorrect, but when educators talk about specific careers and show how what students are learning can lead to these careers, students move to more open-minded images and positive attitudes about such careers (Barker et al., 2006; Scherz & Oren, 2006). This is also potentially important because other studies indicate that while relevant computing curriculum increases girls' interests in computing, it doesn't always increase their belief that computing is of value for their future plans or goals (e.g., Vekiri, 2010). Connecting these activities to future meaningful careers may be one way to bridge this disconnect. See www.ncwit.org/youngwomen and www.dotdiva.org for resources to help make these connections.

Partner with teachers of other subjects. Computing and technology teachers can form effective partnerships with other teachers (e.g., math, science, language arts, graphic arts, art, music) to incorporate computing lessons into these courses. This approach can help teach concepts that need to be taught in these classes in innovative ways and also can go a long way toward showing how computing can be used in a variety of contexts and toward a variety of ends.

Computational Thinking (CT) efforts and resources are particularly helpful in this regard. CT highlights how computer science concepts are used nearly everywhere and how they appear in various problems across many subject areas, making it possible to incorporate CT into all grade levels. By implementing CT across the curriculum and across grade levels, students can experience elements of computer science throughout their school experiences. CT is a fundamental strand of the CSTA (Computer Science Teacher Association) K–12 Computer Science Standards. The CSTA curriculum recommendations include achievable CT standards at every grade level, along with examples of how to incorporate CT into the classroom. For more information, see the ISTE (International Society for Technology in Education) site (http://iste.org/computational-thinking), the CSTA computational thinking site (http://csta.acm.org), and http://www.google.com/edu/computational-thinking/.

* **Incorporate lessons on or discussions of media representations.** Students can analyze popular texts (e.g., movies, advertisements, websites, games) for assumptions and biases related to gender and race and computing (e.g., who's included and who's left out in these texts; what kinds of skin color, clothing, accessory styles are available when creating avatars). They also can play with these norms and assumptions as they create their own technologies to provide more inclusive options around multiple intersections of identities (Denner et al., 2005; Klawe, 2002). Free resources such as CS4FN magazine (http://www.cs4fn.org) can help interrupt stereotypes and challenge problematic media messages (Black et al., 2011).

Pedagogy

- **Use pair programming and other types of collaborative, group work.** Collaborative learning and pair programming has been shown to benefit girls and increase their persistence with computer problem solving (Denner & Werner, 2007; 2009; NAPEEF, 2009). Pair programming also builds networks of support for girls in solving problems and can reduce the uncertainties and discomfort girls sometimes experience in computing classrooms (Denner et al., 2005). In an innovative new twist on pair programming, Dimond and colleagues (2009) developed a way to use chatting capabilities to help foster pair or collaborative programming virtually and with other girls in the class — an approach that was well-received by the girls. Collaborative projects, beyond pair programming, also may be particularly helpful for encouraging interest in computing (Jepson & Perl, 2002; Marcu, et al., 2010; Papastergiou, 2008;). How collaborations occur, however, is important as there is variation in effectiveness. Werner & Denner (2009) identify some of the collaborative interactions that support productive collaboration such as confirming or acknowledging partners' ideas, building or elaborating on partners' suggestions, asking for feedback, disclosing uncertainty, and offering constructive criticism. They also identify interactions that inhibit effective collaboration, including short exchanges that offer a new idea without acknowledging their partner's idea, and disagreeing without trying to understand their partner's perspective.

- **Pay attention to the physical environment of the classroom.** As noted earlier, classroom climate matters for girls' enrollment in CS (Jenson et al., 2003). Part of this climate is the physical space, which impacts their feelings of belonging, fit, and interest in both in-person and virtual spaces (Cheryan et al., 2009, 2011a). Be sure that your classroom contains décor, posters, and other artifacts that appeal to a wide range of students. Minimize more stereotypical kinds of décor like sci-fi posters and Star Trek paraphernalia or make sure that these are balanced with other kinds of décor (Cheryan et al., 2009; 2011a). See the CSTA website for posters that might be useful (**http://csta.acm.org/Resources/sub/BrochuresPostersVideos.html**).

Girls felt they could do COMPUTING because there were other girls doing it around them.

- **Provide frequent, reliable feedback.** This ongoing feedback allows students to more accurately assess their performance without resorting to informal, incorrect metrics such as speed of assignment completion or ability as self-reported by peers (Irani, 2004; see also Barker & Garvin-Doxas, 2004). It is also particularly important for providing girls with a more realistic assessment of their abilities, as they often tend to underestimate these.

- **Pay attention to your interactions with students and be on the lookout for unconscious biases.** Make sure to allocate equal time on the computer for girls; call on girls equally in the classroom; assign difficult problems to girls as well as boys; and spend time equally between girls and boys (Barker & Aspray, 2006; Jepson & Perl, 2002). Partner with a colleague to observe each other's classes for these kinds of patterns.

* **Pay attention to student-student interactions.** Encourage quieter students to speak up, and encourage students to allow others to finish working before they speak up. This helps ensure that speed is not rewarded over a student who takes more time to explore questions or projects (see Barker & Garvin-Doxas, 2004; Clark Blickenstaff, 2005). Also make sure male and female students take on a variety of roles in the classroom (e.g., that girls aren't always the group note-taker) and that they have access to multiple technical roles.

Evaluation

* **Work with administrators to keep track of gendered enrollment patterns.** Or, at the very least, keep track of these enrollment patterns in your own classes. Publicize successes that you have in increasing girls' participation and illuminate for others how you did it.

* **Informally evaluate your efforts and/or partner with researchers to conduct more formal evaluations.** Survey your students for feedback on your course. Work with researchers to improve the knowledge base about what works in making computing more engaging for all students and for increasing the participation of girls and other underrepresented groups.

A Word About Single-sex Education.

Several studies indicate that single-sex education has positive results for girls. *Graduates from all-girls schools are more likely to rate themselves in the highest categories of computer skill competency compared to girls at coeducational schools (Sax, 2009). Another study found that all-girl environments with girl-only peers helped build community and increased girls' self-reported amount of learning. Girls felt they could do computing because there were other girls doing it around them (Jenson, de Castell, & Fisher, 2007). Likewise, a three-year study comparing girls in single-sex computing classrooms to boys and girls in mixed-sex computing classes found that girls in the single-sex classes reported higher levels of* 1) *perceived teacher support,* 2) *confidence, and* 3) *intent to pursue future academic and career options than did girls in the mixed-sex classes. Girls in all-girls classes reported levels as high as the boys (in the mixed-sex classes) on perceived teacher support but lower levels than the boys in confidence. Boys reported higher levels than did girls from mixed-sex classes on perceived teacher support, confidence, intrinsic value, and future intentions.*

What Can School Counselors Do?

* **If there are no computing courses in your school, talk with administrators, teachers, and others about why these courses are important.** In making this case, be sure to distinguish between computer literacy and computer science. See www.ncwit.org/schools for talking points in making this case. Also, visit www.ncwit.org/edjobsmap for an interactive map that provides local, state, and national data on the number of computing graduates versus the number of computing jobs.

* **Consider joining the Counselors for Computing campaign.** Find out how you can join this campaign and help to educate and train other counselors to advocate for change and work effectively with students in guiding them toward computing careers. More information is available at www.ncwit.org/c4c.

* **Dispel myths and talk with parents about the opportunities for computing careers.** Talking points for having these conversations with parents and young women are available at www.ncwit.org/youngwomen. Additional resources that might be of interest to parents, such as the number of computing jobs projected and the salaries of these jobs are also available at www.ncwit.org/edjobsmap and www.ncwit.org/c4c (see the Pathways cards).

* **Talk to students about computing careers and encourage them to enroll in computing courses and/or extracurricular computing opportunities.** Be sure to point out the ways that computing can be used in a variety of fields to solve important problems. Highlight that these jobs are well-paying and likely to be quite plentiful. Visit the NCWIT Counselors for Computing website (www.ncwit.org/c4c) for resources especially designed for counselors to use with students.

* **Help examine scheduling practices and policies that may prevent students from enrolling in these courses.** Work with administrators and teachers to identify how computing may be competing with other electives or other scheduling issues that make it difficult for students to enroll in these courses.

What Can Administrators and Other School District Personnel Do?

* **If there are no computing courses in your school, begin raising awareness and taking steps to implement these courses.** Make sure people understand the difference between computer literacy and computing or computer science; see www.ncwit.org/schools for tips on making this case. Visit www.ncwit.org/edjobsmap for an interactive map that provides local, state, and national data on the number of computing graduates versus the number of computing jobs. These data have been effective in making the case for computing education, and the website includes a report offering examples of how others have used this data. Also check out the

already-developed Exploring Computer Science curriculum at **www.exploringcs.org**. This curriculum has been implemented widely in Los Angeles Unified School District and has dramatically increased African American, Latino, and female enrollment in these courses. Another pilot curriculum by the College Board, CS Principles, is also being implemented and tested in several high schools across the nation (**www.csprinciples.org**). Georgia has four courses in computing that match the ACM model curriculum and Georgia Computes! (**http://gacomputes.cc.gatech.edu/**) has professional development materials for all of these courses.
The Advanced Placement Computer Science A course is equivalent to a college-level CS 1 and there are excellent resources available for that course (**http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/4483.html**).

* **If there are computing courses in your school, examine course scheduling practices and policies that may prevent students from enrolling in these courses.** Identify how computing may be competing with other electives or other scheduling issues that make it difficult for students to enroll in these courses; then change these scheduling options.

* **Offer professional development related to gender and computing for teachers and school counselors.** Ensure that computing courses are actually implementing engaging and relevant curriculum and pedagogies. Ensure that school counselors are encouraging underrepresented students to pursue these careers. Programs like Globaloria, AgentSheets, and others partner with schools to train teachers to incorporate relevant computing curricula into mainstream classrooms. Send teachers to a CS4HS summer workshop (**http://www.cs4hs.com/index.html**) or a Tapestry workshop (**http://www.cs.virginia.edu/tapestry/**) or to the CS&IT conference put on by CSTA (**http://csta.acm.org/ProfessionaDevelopment/sub/CSITConference.html**).

* **Ensure that computing and technology labs are up-to-date and resourced.** This is, of course, vital if teachers are to be able to implement effective and engaging pedagogies in computing classrooms. Work with local industry to find additional resources as possible.

* **Work with state and/or federal legislators and other policymakers to make sure that computing education is an important component of educational policy.** The interactive CS education and jobs map mentioned earlier, and available at **www.ncwit.org/edjobsmap**, can provide valuable local, state, and national data on the number of computing graduates versus the number of computing jobs. These data also are presented by congressional district, specifically for state and national legislators. In making this case, be sure to distinguish between computer literacy and computer science, ensuring that policies encourage practices that involve youth in creating not just using technology. Talking points for making this case are available at **www.ncwit.org/schools**. Also see **http://www.computinginthecore.org/** for additional resources for advocating for computer science education policy.

* **Work with policymakers to adopt CS certification standards and CS curriculum standards.** In making this case, be sure to distinguish between computer literacy and computer science. The Computer Science Teachers Association (CSTA) has developed a set of CS curriculum standards available at www.csta.acm.org, as well as resources for establishing a CS endorsement. A wealth of curricular resources and information on advocacy efforts is also available at the website.

* **Work with policymakers to allow CS courses to count for math/science graduation requirements.** This relatively simple change would help establish computing courses as core curriculum courses and would make it easier and more valuable for students to enroll in these courses. Adding CS to the Common Core State Standards is also essential if your state allows additions.

"Programming? I thought it was all just html and stuff. I didn't really think there was programming for making things move and light up and stuff. I think it's cool how you can…make it do what you want."

—girl reflecting on her experience in a computing workshop for girls (Marcu, 2010)

"It feels good. I actually built something…it looks nice and it actually works. I'm proud of myself and my whole group."

—girl reflecting on her experience in a computing workshop for girls (Marcu, 2010)

A Quick Glance at Promising Programs

While many of the approaches described below have been used primarily in informal education programs, many are also adaptable for formal education and could be incorporated into existing math, science, language arts, or arts courses. The list below is not exhaustive; rather, our aim in this section is to provide an overview of some promising computing programs and their associated outcomes. Some of these program evaluations have been done with larger numbers of students and have produced statistically significant results. Other evaluations have been done with relatively small numbers of students and are more preliminary or exploratory in nature. Nonetheless, these exploratory studies are very important for enhancing our understanding of implementing and refining programs that work to increase girls' participation in computing. A few qualitative studies have also attempted to identify successful classroom strategies in these workshops, and these are important for providing a close look at the day-to-day inner workings of these programs. In this overview, we do not intend to endorse particular programs nor can we give a thorough review of the methodological limitations of each study. Where possible, however, we do note the nature and type of evaluation conducted. Readers should consult the full articles for more details about the nature and limitations of the methods employed.

Informal Education Programs

This section explores programs that range from half-day workshops to multi-year camps. These programs also employ a variety of approaches, including programming languages such as Alice and Scratch, gaming, robotics, website creation, CS Unplugged and other non-wired activities, among others.

Day and Week-long Camps and Workshops. We found many existing programs to be one-day and half-day camps. This may, in part, be because of the convenience and cost effectiveness of one-day interventions. Such camps are generally evaluated based on pre- and post-survey changes in student interest, confidence, and plans to pursue computing.

Many of these short workshops do show promising results. For example, since 2006, Georgia Tech has partnered with the Girl Scouts to offer four-hour Saturday workshops as part of its larger "Georgia Computes!" initiative. In 2007-2008, these workshops reached nearly 1,600 girls, exposing them to computing using LEGO robots, Scratch, PicoCrickets, and/or Alice. Pre- and post-surveys were administered at 13 of these workshops; seven of these workshops showed statistically significant improvement in girls' attitudes about computing when agreeing or disagreeing with statements like "computer jobs are boring," "girls can do computing," and "programming is hard" (Bruckman et al., 2009).

Similarly, Doerschuk and colleagues (2007) report on positive findings for a one-day camp for middle school girls on computer science, including robotics. Students' self-reporting demonstrated an increase in their interest and knowledge of computing from the beginning to the end of the day. Another one-day program took a "school visit" approach, bringing in teams of guest speakers to talk about a range of IT careers, along with programming activities with Alice and Mindstorms NXT robots (Mason et al., 2011). In post-surveys, girls reported that their perceptions of IT careers as difficult had declined. In another study comparing use of Alice with Storytelling Alice, girls using Storytelling Alice were more motivated to program and also reported a stronger interest in taking a future Alice course. Informal assessments also indicated that boys quite enjoyed Storytelling Alice as well (Kelleher et al., 2007; Kelleher, 2008).

These promising programs illustrate how half- and one-day interventions can have some impact on girls' interests in CS courses and careers. Less is known about the long-term impact of these one-day exposures, as there are few longitudinal studies measuring impact over time. One exception is Craig and Horton (2009) who followed up after three months from a one-day workshop with eighth-grade girls. Their survey showed some decline in positive impact from the post-survey immediately following the camp, but it was still higher than before the workshop. More longitudinal research such as this would be valuable (Craig et al., 2008).

Like day camps, one-week camps and workshops also vary in their approach. Some explicitly aim to help girls recognize how computer science can solve real-life problems and the wide range of computing careers available. Graham and Latulipe (2002) offered a week-long workshop for ninth- and tenth-grade girls at the University of Waterloo, showcasing the pervasiveness of CS and expanding stereotypical ideas about what types of people do CS work. Their data showed that girls had already embraced such stereotypes, but that some were debunked during the camp. Pre- and post-surveying also revealed that girls increased their interest and likelihood of taking CS courses, including 81% who reported wanting to take CS courses after the camp. Another week-long camp with 46 middle school girls used Alice along with guest speakers in technology careers. Girls found the program engaging and there were modest increases in interest to pursue a computing career (Webb & Rosson, 2011).

Similarly, a mixed-method study (pre- and post-survey, interviews, observations) of an eight-session computing camp designed to engage low-income girls using activities developed around PicoCricket Kits found promising results. One of the greatest strengths of the program was making participants feel that they had a better understanding of STEM and technical careers (Marcu et al., 2010). A majority of the 53 girls (approximately half White, half Hispanic) also reported an increased interest in STEM because of the workshop and increased confidence and interest in engineering and computer science, in particular.

Another camp called AWE+SUM focuses on math, science, and computing, and has run five times over a three year period (Hu, 2008). During the summertime, girls reported that the workshops using Alice were popular and enjoyable. They also enjoyed collaborative work and grasped basic programming skills. Hu reported that girls varied widely in their ability to follow more advanced programming, like loops or conditionals. These different learning levels presented challenges for teachers in terms of decisions about when to move forward and when to focus on finishing tasks. Sivilotti and Demirbas (2003) reported success with a five-day summer camp of 28 eighth-grade girls where part of the camp focused on teaching elementary components of graduate level CS concepts. In particular, they focused on self-stabilizing distributed algorithms and the concept of fault tolerance. In post-workshop evaluations, the girls reported enjoying the CS unit the most of all the units in the camp. These same researchers also evaluated a later camp with 30 eighth-grade girls. This camp used a combination of programming with Scratch, complemented by additional lessons on advanced computer topics independent of programming language (Sivilotti & Laugel, 2008). Nearly all of the girls (85%) reported that their perceptions of computing were either a little or a lot more favorable.

Georgia Computes! also offers many week-long summer camps for fourth- through twelfth-grade students. These camps are financially self-sustaining and result in statistically significant positive changes in attitudes towards computing. The camps also result in statistically significant learning as measured by pre and post multiple-choice tests. Georgia Tech has helped 11 other colleges and universities in Georgia start computing summer camps as part of Georgia Computes! and these camps also show statistically significant changes in confidence in computing and in agreement that “Girls can do computing” (Ericson & McKlin, 2012).

Summer camps also can have an impact. Pollock and colleagues (2004) evaluated the POWER program, a camp designed for high school girls entering college. They surveyed 21 girls two years after the summer program. Seventy percent of the participants said that the program had a positive impact on taking subsequent mathematics or computer science courses. When asked to what extent their participation in the POWER program improved their confidence in their technical ability, 41% said “a lot” and 48% said “some”, while 12% said “very little to not at all.” When asked what effect the program had on their interest in pursuing a career in a technical or scientific field, 24% said the program significantly increased interest and 35% said that it had increased their interest, while 17% said that it had no impact, and 12% said that it somewhat decreased their interest.

Additionally, undergraduates who served as teaching assistants responded that the program increased their interest in pursuing either a technical or technical education career, and also in participating in similar programs in the future.

Finally, another novel approach being taken by some camps is the use of e-textiles or "wearable" computing technology with Arduino software (e.g., programmable electronic devices that can be sewn into clothing) (Lovelle & Buechley, 2011). Lau et al. (2009) report that students enjoyed wearable computing, and both girls and boys were motivated to learn more about computing and programming. Similarly, Kuznetsov and colleagues (2011) illustrate the impacts of even longer camps using this technology. Their five-week camp focuses on at-risk and lower-income middle school girls. While girls reported frustration with some of the more repetitive tasks, like sewing, the girls expressed enjoyment around working toward a final product to show to family members and friends. Another evaluation of a wearable computing program found that after taking weekend e-textiles workshops, middle school and high school students showed increases from pre to post in interest in "learning more about computer programming," and statistically significant increases in "comfort with programming on their own" and "enjoyment of programming." Both girls and boys expressed similar levels of interest, comfort, and enjoyment before and after the workshop (DuBow & Wu, 2012)

Long-term Camps and Programs. Repeated summer camps offering experiences for returning campers also show promise (see Blair et al., 2010). Adams (2007) reports on three years of summer camps plus one pilot year, using Alice to introduce programming to students before high school. The camps were single-sex camps of both boys and girls. Girls in the 2007 camp reported increased confidence and appreciation of computing. In 2010, Adams followed up with a study of these camps that began using Scratch software in addition to Alice. Through pre- and post-surveys, he found that when asked if they would be likely to return the following year, 60% said "absolutely," 27% said "yes," and 13% said "probably." Approximately 73% of girls said their programming knowledge increased.

The Summer Math and Science Honors Academy (SMASH, **http://www.lpfi.org/smash**) is a five-week, three-year STEM enrichment summer program run by the Level Playing Field Institute in partnership with local universities. The program provides high-achieving, low-income, underrepresented high school students of color rigorous STEM classes, dorm living on college campuses, college preparation courses, field trips, and guest speakers. In addition to project-based, technology-rich traditional math and science courses (e.g., Pre-Calculus, Chemistry, Physics), students also take electives including Robotics, Computer Science, and Entrepreneurship. This program currently serves 214 students at four college campuses in California: University of California, Berkeley, University of California, Los Angeles, Stanford University, and University of Southern California. There are an additional 126 SMASH alumni, who are pursuing post-secondary education or work. Fifty percent of the current scholars are female, and the racial/ethnic demographics are: 53% Latino, 25% African American, 15% Southeast Asian, and 7% other. Based upon data collected over the course of two years, using pre- and post-SMASH impact evaluation surveys, results demonstrate statistically significant increases in computer science knowledge and aspirations to study computer science in high school and college, knowledge of the college application and financial aid process, interest in using STEM knowledge to address community issues, access to female and diverse STEM role models, and diverse networks of STEM peers.

Some summer camps extend into the school year and beyond. Pivikina and colleagues (2009) report on three years of their summer computing camp for high school students, the Young Women in Computing Program (YWiC) from the Computer Science Department at New Mexico State University (NMSU). The camp includes both summer and semester activities, experiential learning of computing in context, and role model and peer mentorship. The YWiC program builds on three principles: **1)** participating students operate as part of cohorts; **2)** computational concepts are introduced in the form of computational thinking, often applied to other domains (e.g., Biology); and **3)** students are continuously exposed to effective role models drawn from all levels of the educational pipeline. The summer program lasts five weeks, and cohorts continue into the academic year to solidify the bonds with the school and provide motivational activities. To sustain the momentum after finishing the program, students are encouraged to participate in the subsequent cycles of the program as peer mentors. After completing high school, students interested in pursuing computer science at NMSU are employed as undergraduate research assistants working for the program.

A longer-term program that appears to offer exciting promise is Digital Divas, a semester-long program that introduces middle school girls to computing using engaging computing experiences. The program also involves university undergraduates as "near-peer" mentors and role models and facilitates interactions with young computing professionals. Both the undergraduate mentors and the computing professionals who spoke to the classrooms helped to break down stereotypes of computing; two-thirds of the girls commented on the post-program, open-ended questionnaires that they would now consider a career in IT. When asked why, most girls reported that this increased interest was due to a better understanding of the variety of things one could do with a computing career (Lang,et al., 2010). Longitudinal effects of this program are currently under investigation (Craig, et al., 2011).

Game Design Programs. Recent years have seen a dramatic increase in the number of programs attempting to expose students to computing through game design. Many of these are short workshops as well, but we include a brief separate section focused on these programs because of their growing prevalence. A study of 62 middle school girls, (70% White; 25% Latina) found that during the 23-session program (2-hr sessions), game design and production, along with pair programming and activities to challenge stereotypes, were effective in addressing many of the social and structural barriers to girls' participation in computing (Denner, et a., 2005). Likewise, game design and programming were effective in helping girls develop skills such as using graphics and databases, as well as more fundamental computing concepts, such as algorithmic thinking (Werner et al., 2006). Similarly, an analysis of 108 games created by middle school

White and Latina girls demonstrated that these girls engaged in moderate levels of complex programming to create these games and that game design and programming can support the learning of computer science concepts (Denner, et al., 2011).

In another study of a small, week-long game design course that also included an introduction to CS and women in the field, five out of nine girls strongly agreed that they were more likely to try computer science in high school after taking this course (Carmichael, 2008). The majority of the girls also noted that they were glad the class was only for girls or that they weren't the only girl in the class. Another small ethnographic study of a program with seven middle school girls (six girls of color) found that when girls created games, it influenced their technical (in this case, engineering) identities. Their developing sense of themselves as technical or as engineers was also significantly influenced by activities where they collaborated and met with external clients and experts. The girls mentioned that presenting their ideas and designs in these real-life contexts and interactions were key instances where they "felt like engineers" (Svarovsky & Shaffer, 2006). Yet another small ethnographic study of a game design program for girls found that girls enjoyed learning real-world technical skills, like Flash, that they can use in broader digital cultures (Cunningham, 2011). This program, however, tended to focus on developing competency rather than fluency which limited some of the outcomes of the program. In a review of literature on games and computing, Kafai (2008), found that game "modding," the ability to modify the programming aspects of a game, does appear to be motivational to students and to increase their computational skill. At the same time, however, others have noted that often the games girls play or the games targeted toward them do not have as many opportunities for modding (e.g., Hayes, 2008a, 2008b). Hayes (2008b) recommends that future game design should ensure that more modding opportunities are built into games that girls tend to play.

Additional programs, like Globaloria (**www.globaloria.org**) and AgentSheets (**www.agentsheets.com**) have begun implementing game design curricula into both after-school and formal school curricula in several states. In many cases, these programs have seen increased enrollments for girls or enrollment rates that exceed the national average for girls in computing courses. For example, in total enrollment in elective courses, Globaloria exceeded the national average, with 33% female enrollment in 2010-11 and 37% female enrollment in 2011-2012 (Wu et al., 2012). While these programs have yet to demonstrate significant increases in interest, confidence, and intent to pursue computing education or careers on pre-/post-surveys, initial evidence is promising. For example, a pilot study of 36 middle schoolers in a two-week course using AgentSheets found that girls and boys reported very similar levels of desire to continue learning AgentSheets (mean 3.1 for boys; 3.8 for girls, with 5 being the highest level of desire) even though at the beginning of the class fewer girls (67% of girls; 96% of boys) had reported an interest in making games (Walter, et al., 2007). Further research is needed to understand this connection. The researchers also found that the program was of particular interest for students who had lower levels of computing or gaming experience coming into the program, indicating that this might be a good approach for those who

"I used pairing throughout the semester. I believe this was useful as most students realized their knowledge of programming was not as strong as they thought. If students worked alone, I would have lost them in the very beginning of the school year."

—computing teacher participating in Tapestry workshop

have had limited prior computing exposure. Ongoing research is underway to further investigate these patterns. In addition to some promising initial results, the integration of these kinds of curricula into the regular school day is an important step for reaching a wider array of students and for making computing a part of the regular, core curriculum.

Culturally Relevant Computing. Another recent and important development in programs for increasing girls' participation is the emergence of culturally relevant computing programs (e.g., Eisenhart & Edwards, 2004; Gilbert et al., 2009; Joseph & Clark, 2009; Scott et al., 2010; Veeragoudar et al., 2010). These programs are especially targeted to students diverse in race/ethnicity and employ established culturally responsive pedagogies (e.g., Ladson-Billings, 2006) to build on students' cultural strengths, assets, and existing knowledge. COMPUGIRLS (**http://sst.clas.asu.edu/about/compugirls**) is one of few such programs focused on girls of color. It seeks to combine culturally relevant teaching, social justice, and technology. Preliminary results have indicated that girls have seen an increase in their knowledge of technological and academic concepts; yet, these boosts were not necessarily encouraging them to see themselves as future technologists. Accordingly, changes have been made to the program and further research is underway to understand how girls' intersecting identities (e.g., race, class, gender, sexuality) shape their participation in these programs and their emerging identities as technologists. Another program aimed at exploring connections between girls' intersecting identities and technology is Digital Mirror, a four-day overnight camp housed at a university setting for middle school girls (Blair et al., 2010). The program is particularly focused on access for underprivileged girls and aims to not only improve girls' technological literacies but also to explore how technology can be a positive part of girls' personal, academic, and professional identities.

Formal Education Programs

Exploring Computer Science is a coordinated comprehensive effort coming out of research conducted in Los Angeles schools (Margolis, et al., 2008). The project includes a K–12/university partnership, the Computer Science Equity Alliance, which is working on changes at multiple levels: **1)** developing curriculum, professional development, and counselor education, **2)** challenging belief systems about who can do computer science, and **3)** political advocacy efforts to institutionalize computer science at the high school level for underrepresented minorities and girls. Since the implementation of the Exploring Computer Science course, African American, Latino, and female enrollment has increased dramatically (see **http://www.exploringcs.org/about/results/ecs-enrollment-data**). While the focus has been on schools in the LAUSD, similar efforts are now being implemented in Chicago public schools, and the downloadable CS curriculum is available to anyone at **www.exploringcs.org**. The Computer Science Equity Alliance is also continuing to develop a model and repository of promising practices (also available at **www.exploringcs.org**) that can inspire similar efforts in other school districts.

Georgia Computes! is an effort to change the computing pipeline from grade four to fourteen (undergraduate) throughout Georgia. Georgia Computes! helped create four computing courses that meet the ACM K–12 model curriculum for high school, as well as curriculum for these courses. It also helped created a CS endorsement that can be added to any teaching certificate. Georgia Computes! was also instrumental in the effort to count the Advanced Placement Computer Science A (AP CS A) course as a science for graduation from high school in Georgia and as a science or math for entry into Georgia's public colleges and universities. As part of its larger "Georgia Computes!" initiative, Georgia Tech's Institute for Computing Education (ICE) partnered with the Georgia Department of Education to offer computing workshops for in-service teachers, even teachers without previous computer science experience (Bruckman et al., 2009; Ericson et al, 2007). One goal of Georgia Computes! was to increase the number of AP CS A teachers. The number of Georgia schools offering AP CS A has increased from 44 in 2004 to 81 in 2008. While other factors have likely been at play in this increase, this program has likely accelerated the development of these additional AP CS A teachers.

The Tapestry Workshop series (http://www.cs.virginia.edu/tapestry/) a relatively new professional development workshop for computer science teachers, provides these teachers with research-based practices for teaching computing in engaging ways and for actively recruiting more girls and youth of color into computer science classes. Feedback from workshops has been very positive, with nearly all participants saying that they would recommend the workshop to colleagues. In the short time the program has been running, several teachers also have reported increases in the number of girls in their computer science classes.

Conclusion and Future Research

This report has provided an overview of the latest research on girls' participation in computing, as well as a model for how a variety of actors can work together to create systemic change. In so doing, we also have identified areas where we know quite a bit and other areas where future research is needed. In summary, we highlight a few of these areas below.

- **We know a lot about the kinds of curricula and pedagogical strategies that work to increase participation of all students, girls included.** Key among these strategies include curriculum that is relevant and makes connections between computer science and the real-life problems that it can help solve, use of pair programming and collaborative work, active recruitment of girls into computing classes, role models that girls can relate to, and early exposure to a variety of computing activities. The challenge now is implementing these curricula and pedagogies at a systemic level.

- **We also know that disparities still exist in different girls' experiences with and access to computing, especially in terms of race and class and the communities in which they live.** Addressing these inequalities is vital for increasing all girls' (and boys') participation in inventing the technology of the future. And to a large extent, we know how to go about doing this as well, as evidenced by some of the promising models that have already begun to transform these conditions for girls and youth of color. Again, the challenge here is implementation and replicating these efforts more broadly.

- **While we have some information about the influence of parents, peers, and popular culture, future research into the exact roles they play is important.** Future research would do well to examine different kinds of parental support and peer influences and how these effect girls' interest and plans to pursue computing. Gaming is also a burgeoning area that seems to hold potential for engaging girls but future research is needed to understand if and how this can be done effectively. Likewise, while we know that media is a powerful influence and some studies have examined the kinds of representations available, few studies have examined how youth actually consume and make sense of these messages. Further work in this area would provide important insights into how these messages are shaping girls' and boys' perceptions of and decisions about computing.

- **We also need more research that moves beyond treating race and gender as demographic categories and instead looks at important intersections of race, class, and gender in students' identity development.** This research should investigate how all girls draw on discourses and messages about race, class, and gender in shaping their identities and how this affects their plans for future education and careers in computing. We also need further research on how we might better develop culturally relevant computing programs that make direct connections between computing and social inequities related to race, class, gender, sexual orientation, and disability. Throughout this report, we have noted how important it is to show girls how computing can be used to address societal problems. Helping them see how technology and computing can be employed in efforts to improve social justice can be an important way of making these connections, especially for youth who are profoundly affected by these inequities.

* **Likewise, while much research has focused on gender more broadly, little research looks at how sexuality shapes girls' perceptions and intentions around computing.** This omission is particularly noteworthy for three reasons. First, sexuality pervades technology and youth lives; indeed, questions or concerns about sexuality are often a significant component of teens' current interactions with technologies (e.g., social media, internet). As a result, attempts to increase girls' participation in computing are likely to have limited effectiveness if we fail to consider how sexuality shapes their experiences with technology (e.g. sexuality-related reasons they are drawn to it or avoid it). Second, existing research identifies work-life issues as a significant barrier women face in choosing and advancing in technical careers (e.g., Simard et al., 2008). Sexuality is central to the decisions girls (and boys) make in this regard (e.g., what kinds of romantic partners they choose, what they want these relationships to look like, if and when to have children, to name only a few). These decisions will have a lasting impact on the kinds of work-life issues these girls face (e.g., Berenson et al., 2007). That we wait until adulthood to address these issues, leaving girls to figure out these complexities all on their own, is short-sighted and likely counterproductive. Third, connecting girls' interest in sexuality to computing activities could be an important way to show girls how computing is relevant to their lives and problems that they care about (e.g., developing technical solutions that raise awareness around sexual health, teen pregnancy, dating violence). While sexuality can be a highly-charged topic, emerging research has shown that connecting curriculum to youth interest in sexuality can, in fact, increase their participation in a variety of academic activities that they previously resisted (Ashcraft, 2008). Exploring the potential of these connections for computing is an important area for future work.

* **More extended research and evaluation of existing programs is needed.** While evaluation of many promising programs has begun, many of these evaluations have been exploratory in nature and have been done with relatively small numbers of girls. More qualitative and quantitative research and evaluation is needed so that we can continue to improve and refine these efforts. While more difficult to conduct, longitudinal research that explores how girls' interests, confidence, and decisions to pursue careers play out over time would also be particularly helpful.

It is our hope that this report will serve as a call for future research in these areas, and that it will enable change agents to more effectively use the research and resources that do exist for increasing girls' participation in computing. Doing so is important for girls, for the future of innovation, and for society at large.

Appendix A: Methodology and Criteria for Inclusion

To identify articles for inclusion in this report, we conducted a number of searches, primarily using Google Scholar, the Digital Library of the Association for the Advancement of Computing in Education, and ERIC. We searched for articles using terms such as gender, girls, technology, information technology, computing, computer science, technology education, curriculum, media, and so on. In addition, we also solicited the help from members of our K–12 Alliance, who also contributed articles from their extensive libraries. These contributions were especially important for helping us gain access to valuable program evaluations and smaller research studies we might have otherwise missed.

We include both research studies and program evaluations because this report aims to not only identify the current state of affairs and key barriers to girls' participation but also to focus on promising practices and solutions for addressing these barriers. The criteria below help to ensure that the research reviewed here is reliable and of high quality. In an effort to keep this report a manageable length, we are unable to provide detailed methodological reviews regarding the merits and limitations of individual articles or studies; however, where possible, we do attempt to indicate the size and nature of individual studies, as well as identify where strong evidence exists for particular findings and where future research is needed.

We used the following criteria for selecting research articles and program evaluations for inclusion:

- Research and evaluation articles must be published in a peer-reviewed venue (e.g., journal, book, conference proceedings) or must be conducted and disseminated by a reputable organization (e.g., AAUW, Girl Scouts). Because much of the research on girls and IT is recently and rapidly emerging, we include a number of more preliminary or exploratory studies, but these must appear in a peer-reviewed venue, such as SIGCSE or other conference proceedings.
- Research or evaluations must focus primarily on computing, information technology, or computer science specifically, rather than STEM broadly. In some cases, we made an exception if there was a valid reason for doing so (e.g., to inform a significant gap in the computing-specific literature). We explain the rationale for any such exceptions within the report.
- Research or evaluation must focus on students' interest in, attitudes toward, and participation in creating or adapting technology rather than merely consuming or learning with it.
- Research or evaluation should include a focus on gender or girls. In some cases, studies that focus on K–12 students and computing, but not on gender, were included if there was a reason to do so for comparative or other kinds of purposes.

* Research or evaluation must also focus on the K–12 level. In some cases, we included research or data related to undergraduates if it was also likely to be applicable to or shed light on circumstances at the K–12 level. For example, while Sapna Cheryan's work (e.g. 2009) with the ways in which environments that are stereotypically "geeky" influence women's choices to pursue computing was mostly conducted with undergraduates, it carries very relevant insights for K–12 environments as well.

* This report focuses on U.S. students and contexts, although some studies from English-speaking and other Western European countries were included if they were particularly relevant or helped to fill a gap in the literature. In general, we follow Barker & Aspray (2006) in excluding studies from other countries because we know that differences in culture, language, and policy make it difficult to draw accurate comparisons between these countries and the U.S.

We used additional criteria for selecting research and evaluation for inclusion in the third section of this report on promising practices for addressing barriers:

* Practices, programs, or curricula must have some evaluative evidence of "success" in increasing girls' interest or participation in computing (further defined below) in at least one context or setting.

* "Success" includes demonstrating one or more of the following kinds of criteria (as found by survey, interview, ethnographic, or similar kinds of research and evaluation methods):
    - Increasing girls' interest in computing
    - Increasing girls' plans to take additional computing courses or enroll in other kinds of computing programs
    - Increasing girls' intention to major in computing
    - Increasing girls' plans to pursue a computing career
    - Positively affecting girls' attitudes about computing or creating new technologies
    - Positively affecting girls' confidence or sense of themselves as "technologists" or as "good" at computers/computing (or similar kinds of self-perceptions/identity questions related to computing and creating with technology)
    - Improving girls' actual (as opposed to self-perceived) technical skills and abilities (e.g., as measured by assignments or other assessments)

* Practices or programs without evidence of success specifically in computing may be included to fill specific gaps in research/evaluation if they are based on sound educational theory, include practices proven to be effective in other curricular areas, and, are therefore, likely to be promising given what we know from past educational research and practice.

Appendix B: A Word About Theoretical Perspectives

As Barker and Aspray (2006) note (and as we briefly discuss in the introduction), research on IT and computing often uses social science paradigms that enforce (post-)positivist and functionalist viewpoints (Burrell & Morgan, 1979). Such perspectives employ a perspective on sex or gender that takes for granted a traditional male-female dichotomy and ignores how these categories are in fact socially constructed and performed. These perspectives see biological sex (male/female) and gender as mapping perfectly onto one another, espousing that there are two and only two genders and that these are mapped onto two and only two sexed bodies. This mapping also sometimes follows cultural discourses of boys and girls as having innate, natural, biological differences (e.g., boys are rougher; girls are more loving). While exceptions to this trend do exist (see Abbiss, 2008; Clegg, 2001; Jenson, de Castell, & Bryson, 2003; Stepulevage, 2001), much of the literature on gender and computing employs this perspective, often treating gender as a "check this box or that box" type of variable.

A variety of scholars in interpretivism, social constructionism, feminism, critical theory, and post-structuralism have illustrated the limitations of these assumptions. These scholars suggest that gender is "an emergent feature of social situations: both as outcome of and rationale for various social arrangements and a means of legitimating one of the most fundamental divisions of society" (West & Zimmerman, 2002, p. 4). These theorists problematize the naturalization of gender differences and explore the historical organization of sexes and genders (de Beauvoir, 1953; Scott, 1986; West & Zimmerman, 2002). In so doing, they illustrate how we are not born with but rather are rigorously recruited to our gendered identities, how we perform and reproduce these identities in everyday interactions, and how this has real implications for employment, relationships, identities, and social change. Thus, rather than view gender as simply another variable to measure, a role, or an individual attribute (see Fenstermaker, West, & Zimmerman, 2002), our report positions gender as socially constructed categories that need to be examined. As Barker and Aspray (2006) explain, "We understand gender to be a set of social categories that shape not only tacit beliefs about how a girl or a boy believes that she or he should behave but also the way that others treat girls and boys as gendered beings, and the way others interact with boys and girls based on deeply ingrained expectations about how they should respond" (p. 10).

While the scope of this report is on girls and IT, we note that men also perform their gender and hold one another accountable for such performances (Connell, 1995). Gender studies are often only seen as studies on women or "women's ways" of doing things. While, in this report, we do focus on girls in IT, we are aware of the ways in which femininity and masculinity discourses shape one another and believe that it is also important to consider how men, masculinity, and occupations are as much a part of the story of girls in IT as girls themselves are (see Acker, 1990, 2006).

Of course, gender is not the only difference that makes a difference, and we would be remiss to end our theoretical discussion here. Audre Lorde famously wrote about the arrogance "to assume any discussion of feminist theory without examining our many differences, and without a significant input from poor women, Black and Third World women, and lesbians" (1984, p. 15). Privilege acts as a veil covering what we explore in our inquiries (Alexander, 2005), and we must also consider our own positions of privilege as researchers and how to be open to other politics than our own. Contemporary research in gender and computing, then, should explore the importance of other intersections of difference and experiences of inequality (Acker, 2006; West & Fenstermaker, 2002). This research should investigate the complex ways in which girls and women, diverse in race/ethnicity, class, ability, and sexuality, make sense of their multiple, intersecting identities and the implications of this for their participation in computing. While a few scholars have begun such work (e.g., Kvasny et al., 2009; Yakura, 2006), we call for more intersectional inquiries into all markers of difference and suggest that this is a crucial next step in efforts to diversify computing.

Appendix C: K–12 NCWIT Resources

A number of complementary NCWIT resources regarding K–12 computing education are available at www.ncwit.org. These include:

The Scorecard: The NCWIT Scorecard shows trends in girls' and women's participation in computing in the U.S. over time, providing a benchmark for measuring progress and identifying areas for improvement. Download PowerPoint slides and charts (.JPG modules) from individual sections for your own presentations, proposals, reports, etc. Available at www.ncwit.org/scorecard.

Computing Education and Future Jobs Interactive Map: NCWIT provides an interactive map that presents education and workforce data at the national, state, and congressional district level. Use this map and the other tools on this site to influence educators, legislators, administrators, parents, and other decision-makers where you live or work. See www.ncwit.org/edjobsmap.

Counselors for Computing Campaign (C4C): Counselors for Computing (C4C) is a four-year campaign that equips counselors with up-to-date information and resources they can use to advise students — especially girls — regarding education and careers in IT. See www.ncwit.org/c4c.

Why Should Young Girls Consider a Career in Information Technology? This "talking points" card gives adults talking points and additional resources for a conversation with their daughters and/or other young people. Information is provided to address these specific questions: What should you tell a young woman about a career in IT? How can a young woman prepare now for a career in IT? Available at www.ncwit.org/youngwomen.

Moving Beyond Computer Literacy: Why Schools Should Teach Computer Science? This "talking points" card provides information about the value of computer science curriculum for students, educators, local and national economies as well as global society. It offers tips for making this case with curriculum decision makers and suggests steps that schools can take to successfully incorporate computer science education. Available at www.ncwit.org/schools.

K–12 Promising Practices and Programs-in-a-Box: NCWIT offers a number of short case studies describing promising programs and practices for improving K–12 curriculum and increasing girls' participation in computing. Also available are Outreach-in-a-Box: Discovering IT (www.ncwit.org/outreach), a toolkit for industry professionals who would like to be guest speakers in K–12 classrooms, and Computer Science-in-a-Box: Unplug Your Curriculum (www.ncwit.org/unplugged), a toolkit for introducing computing in engaging, "non-wired" ways. All of these resources are available at www.ncwit.org/resources.

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Girls in IT: The Facts

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