Examination of Practices Used By AP Computer Science Teachers with Higher Than Average Female Enrollment

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ABSTRACT

EXAMINATION OF PRACTICES USED BY AP COMPUTER SCIENCE TEACHERS
WITH HIGHER THAN AVERAGE FEMALE ENROLLMENT

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Department of Curriculum and Instruction
Northern Illinois University, 2020
Elizabeth A. Wilkins, Director

This dissertation examines the practices employed by AP Computer Science A teachers that can help recruit and retain female students in computer science. A survey was sent to teachers to see what practices they used in their classrooms and what practices they thought had the biggest influence on female student recruitment and retention. Of the five practice categories (recruitment, pedagogical, curricular, extracurricular, and mentoring), the survey respondents thought recruitment was the most influential and curricular was the least influential. After the survey, 12 teachers were chosen for interviews because they had a higher enrollment of female students than the rest of the survey respondents. These teachers believed that pedagogical practices were the most influential. They specifically mentioned using pair programming in the classroom as a means of building a positive classroom culture and helping all students through difficult programming problems.

This research showed that recruiting and pedagogical practices were essential tools for teachers to increase the gender diversity of their AP Computer Science A classrooms. Future research can see if these practices apply to other STEM fields, if a real-world creative curriculum can increase female recruitment and retention and if an introductory female-only computer science course could influence enrollment.
NORTHERN ILLINOIS UNIVERSITY
DEKALB, ILLINOIS

AUGUST 2020

EXAMINATION OF PRACTICES USED BY AP COMPUTER SCIENCE TEACHERS
WITH HIGHER THAN AVERAGE FEMALE ENROLLMENT

BY

DEREK JOSEPH MILLER
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A DISSERTATION SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE
DOCTOR OF EDUCATION

DEPARTMENT OF CURRICULUM AND INSTRUCTION

Doctoral Director:
Elizabeth A. Wilkins
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Finally, I need to thank my wife Christie for supporting me with the gift of time. When I started this process she was pregnant with our oldest son Paul, and now we have added our daughter, Danielle, and twin boys, Luc and Sam. Allowing me to go to the library and work on this research is a gift I do not believe I can ever pay back.
DEDICATION

For my wife, Christie. Thank you for supporting me and giving me the time to do this. I love you more than you will ever know.
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CHAPTER 1

INTRODUCTION

The power of computer science lies in augmenting our thinking and in its ability to accelerate research exponentially in other areas. Even areas as diverse as art, economics, medicine and political science can benefit from integrating computational thinking into their research and education. The possibilities are endless. (Ottino as quoted in Morris, 2016, p. 16)

Julio Ottino, dean of Northwestern University’s McCormick School of Engineering, is not alone in thinking that computer science can benefit numerous fields of study. People both inside and outside the computer industry have expressed a belief that computer science is the key to the advancement of society because of its connection to diverse fields of study (e.g., Connolly, 2016; Lazowska, 2011; National Science Foundation, 2009; Tufekci, 2011; Wholsen, 2014). Many universities have recognized the importance of connecting computer science to other fields and have introduced CS+X programs that combine a computer science major with another major (Board of Trustees at the University of Illinois, 2016; Robert R. McCormick School of Engineering and Applied Science, 2017; Stanford University, 2017).

As computer science connects to other fields, it is important that the workforce within computer science is a gender diverse workforce. Females are one underrepresented group that stands out. Females comprise 43 percent of the full-time workforce and 64 percent of the part-time workforce in the United States (U.S. Department of Labor, 2016), but only 12 percent of the computer science field (Google Inc. & Gallup Inc., 2016). A diverse workforce can help prevent groupthink within an organization, and the field of computer science is no exception to this rule
(Fine, 1996; Roach, 2007; Simerly, 1991). One example in which a lack of gender diversity hurt product development was Google’s Translate program. Schiebinger, Sánchez de Madariaga, Paik, Schraudner, and Stefanick (2013) found that Google Translate defaulted to the male pronouns because male pronouns are twice as likely to appear on the web compared to female pronouns (Schiebinger et al., 2013). Since many web developers use Google Translate to provide different language versions of their websites, automatically defaulting to a male pronoun means the proportion of male to female pronouns on the web will increase to make the gender pronoun gap even more profound. Early voice recognition systems are another example of how a lack of gender diversity can have unintended consequences. Voice recognition was initially designed by all-male teams, and the software had difficulty recognizing female voices (Margolis & Fisher, 2003). While voice recognition software is better today, male voices are successfully recognized more often than female voices (Tatman, 2017).

Getting more females involved in computer science has been the goal of the computer science industry for some time and has more recently become a goal of university computer science departments. However, research shows females lose interest in computer science at an early age (Cheryan, Drury, & Vichayapai, 2013; Margolis & Fisher, 2002), so it may be up to elementary and secondary teachers to spark females’ interest in computer science to help diversify the workforce in the computer science industry. To that end, this study focused on the AP Computer Science A course since it is the most prevalent nationwide course for computer science in secondary schools with a common end exam (College Board, 2018). Using the AP Computer Science A course also ensures an available population of teachers to contact for data gathering. AP Computer Science A is a course meant to mirror a freshman-level college
computer science course, and students can earn college credit if they pass the AP Computer Science A exam with a score of three or higher out of five.

Research Framework

Lather (1991) contended that students, specifically female students, were oppressed in classrooms with teachers in the traditional role as purveyors of all knowledge. Lather’s theory was not meant to be anti-male but instead a way for teachers to improve their pedagogical practices to be more inclusive of female students. Lather argued that if teachers and the curricula were more inclusive of female students, those students would be more willing to take risks and accept challenges they might otherwise shy away from. While outright gender bias may not be a problem for most females in computer science, subtle bias can be an issue (Sandler & Hall, 1986; Lather, 1991; Margolis & Fisher, 2002). Female students can be made to feel like they do not belong in computer science, even if those who make them feel this way have the best intentions (Margolis & Fisher, 2002). Teachers can play a large role in whether female students pursue a STEM career, and there are ways teachers can work to ensure they are encouraging rather than stifling female interest in STEM.

The concept of gender equity is applicable to females in STEM fields, as the percentage of females in STEM is much lower than in other fields (Cohoon & Aspray, 2006; Google Inc. & Gallup Inc., 2016). While there are many barriers to females entering the computer science field, there are potential solutions to closing the gender gap in computer science that are addressed in the Next Generation Science Standards’ (NGSS) emphasis on including underrepresented groups. While only two NGSS standards directly apply to computer science, the NGSS identifies
three main areas that can positively change females’ achievement, confidence, and enjoyment in the science classroom. Those three areas are instructional strategies, curricula, and organizations such as mentoring programs and after-school clubs (Baker, 2013; Scantlebury & Baker, 2007). Focusing on the equity parts of the NGSS framed the current study on high school AP Computer Science teachers’ practices for including female students in their classes.

Problem Statement and Purpose of Study

The computer science industry in the United States, and in many Western countries, has a well-known problem with diversity (Cheryan et al., 2013a; Cohoon & Aspray, 2006; Google Inc. & Gallup Inc., 2016; Margolis & Fisher, 2002; Zweben & Bizot, 2017). Demographics of computer science departments at the university level and demographics of the industry show the field consists primarily of Asian and Caucasian males, with females only making up a small percentage of both the industry and undergraduate computer science degrees. The 2016 Taulbee Survey found that only 18.1% of students enrolled in computer science, computer engineering, or information courses at the college level in the United States and Canada were female (Zweben & Bizot, 2017). The Taulbee Survey has been conducted every year since 1974 to track the number of students who graduated with computer science, computer engineering, or information degrees in the United States and Canada.

The percentage of female students earning computer science-related degrees has only changed marginally during a recent period of steady growth for all populations earning computer science degrees. In recent years, the percentage of female graduates in computer science-related fields was 13.3% in 2012 (Zweben & Bizot, 2013), 14.5% in 2013 (Zweben & Bizot, 2014), and
14.7% in 2014 (Zweben & Bizot, 2015). It is too early to tell if increases in the number of female graduates of computer-science related fields to 16.3% (Zweben & Bizot, 2016) and 18.1% (Zweben & Bizot, 2017) are an aberration or part of a trend. The National Science Foundation reported that 24.7% of mathematical or computer scientists in the field were women in 2016. This was down from 26.6% in 2006 (National Science Foundation, 2015), showing that the industry may actually be experiencing a decline in terms of including women.

While there is a wealth of research available at the university level on the gender gap in computer science, little research examines secondary students in computer science. The only available research is too narrow: looking at specific issues such as learning styles (Lau & Yuen, 2010) or focusing on smaller populations (Ericson, Parker, & Engelman, 2016; Goode, 2007). However, the lack of female students in university computer science programs is widely believed to start earlier than college (Margolis & Fisher, 2002; Tsan, Boyer, & Lynch, 2016), which emphasizes the need to increase female enrollment in high school computer science classes. Therefore, the purpose of this study was to investigate practices used by computer science teachers who had a higher than average enrollment of female students in their AP Computer Science A classes. This study focused specifically on AP Computer Science A classrooms, as that is the most common computer science curriculum used throughout the country.

Research Questions

This study focused on the following research questions:

1. What practices do computer science teachers employ who have a higher than average enrollment of female students in their AP courses? Categories of practices include
a. Recruitment
b. Pedagogical
c. Mentoring
d. Curricular
e. Extracurricular

2. How do computer science teachers use those practices to increase female students’ enrollment in AP Computer Science A? When and how often are they employed?

3. Which practices do computer science teachers perceive as most and least influential for increasing female student enrollment in AP Computer Science A courses and why?

Significance of the Study

Research has shown a gender gap in the field of computer science (Cheryan et al., 2013a; Cohoon & Aspray, 2006; Google Inc. & Gallup Inc., 2016; Margolis & Fisher, 2002; Zweben & Bizot, 2017) and evidence that the gap begins before college (Margolis & Fisher, 2002; Tsan et al., 2016). Past research has found ways to increase female participation in university computer science programs (Alvarado & Dodds, 2010; Gharibyan & Gunsaulus, 2006; Margolis & Fisher, 2002; Othman & Latih 2006; Spice, 2014), but many of the approaches involve outreach to high school students (Ericson et al., 2016; Margolis & Fisher, 2002; Sanders, 1994). Existing findings indicate that the gender gap can be resolved if high school teachers make efforts to increase female participation in their programs, and this study can serve as a resource for high school computer science teachers who seek to increase female participation in their courses. It will also
benefit female students who may not realize they have an interest in or talent for computer science until they take a computer science class.

Methods

This study used a transformative, sequential, mixed methods design in which the quantitative data were used as the basis for the qualitative data (Teddlie & Tashakkori, 2009). High school AP Computer Science A teachers 22 to 70 years old were the focus of this mixed methods study. Data were collected at two different times. I collected the quantitative data through a survey of AP Computer Science A teachers and the qualitative data through interviews with selected AP Computer Science A teachers. The mean was used to determine the average number of female students taught by each teacher in the sample during the previous and current school years. The mean was also used to calculate the average AP Computer Science A exam score for female students as well as students in general in each school. The standard deviation was calculated for the number of female students in each class. Teachers were also asked why they chose their most and least influential practices for recruiting and retaining female students. These data were analyzed by reading through the responses and developing codes that were also used in the interview transcription analyses. After the interviews were transcribed, memoing was employed to take notes on the transcriptions and ask questions about the teachers’ responses (Creswell, 2013). These memos attempted to capture themes prevalent in each interview. After initial memoing, I developed codes and attached those codes to the transcriptions.
Definitions

The following definitions help to clarify terms introduced throughout this study.

**Algorithm:** A series of steps written to perform a task on a computer. An algorithm is often written in pseudocode first and then translated into computer code for a computer program (Turing, 1936). Algorithms are an integral component of computer science and make up a substantial portion of any computer science course.

**Computer Programming:** The process of writing computer code to create a software application or task for a machine (Blackwell, 2002).

**Computer Science:** The study and implementation of algorithms to efficiently automate tasks. Computer science is not using computer programs such as word processing or spreadsheet software that are typically a part of a computer applications course in high school. Computer programming is a major part of the implementation of computer science algorithms, but it is not the entirety of the field (Denning, 2005).

**Gender Bias:** Treating people differently based on their gender. This can be done consciously or unconsciously (Lather, 1991).

**Gender Gap:** A difference between the proportion of males and females in a particular field that does not match the gender difference in the general population. For example, if the general population was half male and half female, a field that had 60% males and 40% females would constitute a gender gap (Margolis & Fisher, 2002).

**Gender Parity:** Achieving the same result for both genders. This could involve eliminating the gender gap in a particular field, but it could also make sure women and men are paid the same for the same work (Margolis & Fisher, 2002).
Organization of the Study

This study consists of five chapters. Chapter 1 serves as the introduction to the study and provides the rationale, theoretical framework, and definitions for the study. It also introduces the problem statement, purpose of the study, and research questions. Chapter 2 provides a review of the relevant literature investigating females in the field of computer science and females in the computer science classroom. Chapter 3 describes the methodology used to conduct this study. Chapter 4 presents the quantitative and qualitative findings of the study. Finally, Chapter 5 discusses the findings of this study and the implications for future research.
CHAPTER 2

REVIEW OF LITERATURE

This chapter begins with a discussion of the research framework that utilizes a portion of the Next Generation Science Standards. The chapter continues with a history of computer science in the United States and how females have contributed to the computer science industry. Then the next major section details the computer science gender gap in other countries before discussing why gender bias is a problem. The bulk of this chapter presents reasons why females are underrepresented in computer science.

Research Framework

The Next Generation Science Standards (NGSS), particularly their emphasis on underrepresented groups, served as a framework for this study of gender inequity in computer science.

Next Generation Science Standards

While the Next Generation Science Standards (NGSS) are not directly connected to computer science, some of the practices are relevant to the subject. The NGSS came about after a 2009 Carnegie Foundation commission determined that a strong foundation of math and science was necessary to preserve America’s economic and educational competitiveness (Carnegie Corporation of New York, 2009). After this report, the National Research Council (NRC, 2012),
the National Science Teachers Association, the American Association for the Advancement of Science, and an independent organization named Achieve dedicated to raising academic standards went through a two-step process over four years to develop a set of science standards (NGSS Lead States, 2013).

The first step of the NGSS development process was to create a framework called the Framework for K-12 Science Education. The NRC established a committee of 18 practicing scientists and science education experts to develop this framework. In addition, four teams developed parts of the framework for specific areas of science, including physical science, life science, earth/space science, and engineering. The final framework was released to the public in July of 2011, with an updated version released in 2012 (National Research Council, 2012).

Achieve managed the second step of the NGSS development process, while the states led the actual development of the standards. All of the work on the standards was tied to the Framework for K-12 Science Education. Stakeholders helped develop the standards along with the states, and the NRC ensured the fidelity of the standards and concluded they were consistent with the Framework for K-12 Science Education (NGSS Lead States, 2013).

**Three Dimensional Learning**

The Framework for K-12 Science Education and the NGSS are based on three essential dimensions in science. The first dimension describes practices scientists engage in as they build models about the world and practices engineers use to design and build things. Scientific inquiry drives scientific practices, while engineering design drives engineering practices. Scientific inquiry has students follow the scientific method to test the models and theories about the world.
Engineering design is similar to scientific inquiry but uses science, technology, engineering, and math to create a digital or physical product (NGSS Lead States, 2013). The second dimension of the NGSS includes concepts applicable across all domains of science. These crosscutting concepts incorporate patterns, cause and effect, scale, system models, energy and matter, structure and function, and stability and change (NGSS Lead States, 2013).

The final dimension of the NGSS involves the disciplinary core ideas to help focus the curriculum on key aspects of science. Ideally, the core ideas should meet at least two of the following criteria: be of broad importance across multiple science or engineering disciplines or be a key organizing concept of a single discipline, provide a key tool for understanding more complex problems, relate to the interests and life experiences of students, and/or be teachable and learnable over multiple grades at increasing levels of sophistication (NGSS Lead States, 2013). While the NGSS does not have a lot of direct connections to computer science, there are three areas of the standards that could apply to the current study: engineering design, underrepresented groups, and curriculum.

**Engineering Design**

Engineering design is the process engineers use to plan products to solve a given problem. It is similar to the scientific method and is a driving force of the NGSS. A definition of engineering design is provided in the Framework for K-12 Science Education:

In the K–12 context, “science” is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences . . . . We use the term “engineering” in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. Likewise, we broadly use the term “technology” to include all types of human-made systems and processes—not in the limited sense often used in
schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants. (National Research Council, 2012, p. 11-12)

Computer science draws heavily from the principle of engineering design. Computer scientists are sometimes referred to as software engineers because the process of designing a software solution to a problem follows a model of software development similar to how engineering design follows a design model. While the models may differ, the general structure of the models moves from a planning stage, to a prototype stage, to a production stage, and finally to a testing stage.

The NGSS use engineering design as a core tenant because the developers of the standards believed engineering design practices are something all citizens should learn (NGSS Lead States, 2013). Engineering design clearly applies to computer science, and the process students must follow for problem solving engineering design is certainly applicable to other fields of study and careers.

**Underrepresented Groups**

The Framework for K-12 Science Education (National Research Council, 2012) affirmed that students from different backgrounds are capable of achieving in science classrooms and scientific fields if they are given equitable learning opportunities. This follows from the NRC’s earlier reports such as *Taking Science to School* (2007); *Ready, Set, SCIENCE!* (2008); and *Learning Science in Informal Environments* (2009) along with research from numerous other sources about underrepresented groups in STEM fields (Beyer, 2014; Bock, Taylor, Phillips, & Sun, 2013; Goode, 2007; Google Inc. & Gallup Inc., 2016; Litzler, Samuelsen, & Lorah, 2014).
The NGSS identify seven groups that should be targeted to increase diversity in the science classroom. The first four groups – economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, and students with limited proficiency in English – were previously identified by the No Child Left Behind Act of 2001. The other three groups – females, students in alternative education programs, and gifted and talented students – were identified exclusively in the NGSS (NGSS Lead States, 2013). Focusing specifically on females, the NGSS notes that research has identified three main areas that can positively change females’ achievement, confidence, and enjoyment in the science classroom. The NGSS identifies those three areas as instructional strategies, curricula, and organizations such as mentoring programs and after-school clubs. Utilizing these three areas to engage females in the science classroom is key to recruiting and retaining them (Baker, 2013; Scantlebury & Baker, 2007).

The NGSS presents seven case studies highlighting the importance of diversity in science classrooms although only one case study focuses on female students (NGSS Lead States, 2013). The case study on females focused on a third-grade engineering classroom in which the teacher chose a project relevant to the students and had a real-world application. This was a key instructional strategy that could engage females as well as other underrepresented groups in science. Engagement at an early age is key to females considering STEM. By creating lessons and projects that appeal to all students, female students can become more engaged at an earlier age and reduce the achievement gap between male and female students in STEM (NGSS Lead States, 2013).

An instructional strategy specific to females brought up in this case study was bringing in female experts to speak to the class, which was shown to increase females’ confidence in science
Guest speakers have been found to be helpful for many disciplines, but in a finding that appears to be specific to computer science, guest speakers who portray negative stereotypes of the field can actually have the opposite affect and drive females away from computer science (Cheryan et al., 2013a). Another instructional strategy addressed in this case study was carefully planning student groups. While the case study did not discuss how the groups were chosen, research shows that pairing like-ability students can have the greatest affect (Braught et al., 2010). A final instructional strategy the case study addressed was to have students generate the problems and potential solutions used in classroom activities. This strategy can motivate all students to engage in science, including females (NGSS Lead States, 2013).

While the case study did touch on how the NGSS connects the case study activity to the standards, it did not specifically address how this helps females.

Curriculum

According to the NGSS, curriculum is one of the three ways teachers can achieve gender parity in their classroom (NGSS Lead States, 2013). Marcu et al. (2010) designed a curriculum for middle school females to engage them in computer science and engineering. They used hands-on PicoCrickets for this course, which let students create musical sculptures, interactive jewelry, and dancing creatures (Playful Invention Company, 2016). Marcu et al. used pre- and post-surveys as well as interviews to gauge the females’ attitudes toward computer science and engineering. This study was done with one sample of females during one summer course. The study used a mixed methods approach and created a curriculum that teachers can implement in
the summer or after school. In addition, it is always helpful to have an artifact, in this case a curriculum that can help females become interested in computer science.

Another computer science curriculum was developed by Hansen et al. (2016) using the universal design for learning (UDL) process for students in grades four through six. This curriculum was used in 15 different California classrooms from five different schools, reaching 400 students during the 2013-2014 school year and 1,500 students during the 2014-2015 school year when the program expanded to include more California schools. Hansen et al. used differentiated instruction as a crucial component for how teachers can reach underrepresented groups in computer science. They determined what students struggled with and tailored the instruction to address those needs. For example, some of the students struggled to read the material without assistance, and the students misinterpreted some vocabulary, such as the word glide. Furthermore, some students did not have grade-level math proficiency, which caused confusion when they had to use negative numbers on a coordinate plane. Some students complained that the characters they could include in the programs they created did not look like them, showing the need for diversity in human images within the classroom. Gender bias can be inadvertent, and females can be made to feel a certain way that will lead to them avoiding certain activities (Lather, 1991). This study showed that female students notice when they are underrepresented in the computer science classroom, so it is important that people they see (either in person or through images) sometimes look like the students to help their sense of belonging.

Alvarado and Dodds’ (2010) college level study sought to find ways to increase the percentage of females in computer science at Harvey Mudd College. They did this by creating a
broader introductory computer science course containing elements connecting computer science to the community, recruiting first-year students by taking them to the Grace Hopper Celebration of Women in Computing, and hiring undergraduate students to work on research projects. The Grace Hopper Celebration is a four-day event that brings women in technology together to celebrate their achievements. The curriculum, although focused on college students, was meant to broaden interest in computer science by injecting more creativity into courses and avoiding too many projects that just focused on math problems. There were five females in computer science at Harvey Mudd College in 2006 when the project began, and 13 in 2008. As of 2018, the college had a female computer science enrollment of 56% (Harvey Mudd College, 2018), showing that a focus on curriculum, as recommended by the NGSS (NGSS Lead States, 2013), can help achieve gender parity.

While not a curriculum on its own, Ericson et al. (2016) explored the program called Sisters Rise Up 4 CS, which provided tutoring for female students who were enrolled in the AP Computer Science A course at a high school in Georgia during the 2014-2015 school year. While the study did not focus on the recruitment of female students in computer science, it did focus on retaining female students through improved performance on the AP Computer Science A exam. The study cited research on how peer groups helped female students persist in computer science, specifically citing Bandura’s social learning theory (1977) in that people learn by observing from other people that are similar to them. This program also helped provide strong mentors for female students, which the NGSS believes contributes to female persistence (NGSS Lead States, 2013).
Early research has shown that female students lose interest in computer science as they get older (Cohoon & Aspray, 2006; Margolis & Fisher, 2002). Brinkman and Diekman (2016) believed communal goal congruity is a concept that contributes to this phenomenon. A communal goal is a goal that focuses on working with, or in the service of, other people. Communal goals typically have an altruistic focus. Brinkman and Diekman worked on a long-term intervention with a communal goal congruity perspective in mind. Their program was designed for computer science students who live together in the dorms and take at least two courses together. Students also had to participate in one service learning activity per year that could be satisfied by taking courses with embedded service learning opportunities. At the time of paper, early results indicated students were selecting the service learning program for reasons other than the scholarship money and those students were more diverse than the general population in computer science. This diversity was manifested through gender and racial diversity even though Brinkman and Diekman wanted to focus on increasing female participation. Similar to the work at Harvey Mudd College (Alvarado & Dodds, 2010), this study shows the impact curriculum can have on gender diversity.

History of Computer Science in the United States

The computer science industry in the United States, and in many Western countries, has a well-known problem with diversity. The demographics of computer science departments at the university level and in industry show computer science mainly consists of Asian and Caucasian males. Zweben and Bizot (2017) have conducted the Taulbee Survey every year since 1974 to
track the number of students who graduated with computer science, computer engineering, or information degrees in the United States and Canada.

The original survey was designed to provide information about Ph.D.s in computer science, but over the past few decades, the survey administrators have expanded it to include information on undergraduate computer science students (Zweben & Bizot, 2017). The demographic information has shown steady growth in computer science degrees awarded starting in 2009. However, although the number of degrees awarded is now greater than the number during the peak of the 1990s internet boom, the percent of female students earning computer science-related degrees has only changed incrementally during a period of steady growth (Zweben & Bizot). Data on the industry are not much better, with the National Science Foundation (2015) reporting that 24.7% of mathematical or computer scientists were female in 2016, which was down from 26.6% in 2006.

Companies have had to hire foreign workers to make up for the lack of domestic college graduates (U.S. Department of Labor, 2014). Statisticians report that this shortage will only become worse (Bureau of Labor Statistics, 2015). One way to solve it is for recruiters to attract a more diverse workforce (Roach, 2007). Females are easy to target since they make up half of the population but less than a quarter of computer scientists. Recruiters are also targeting other underrepresented groups such as Latinos and African Americans.

**Female Contributions to Computer Science**

Ensmenger (2012) wrote a history of computers that did not focus on computers per se but instead on the important programmers behind those computers. While he did not set out to
determine causes of the gender gap, he did discuss many of the female programmers in the early
days of computers, such as Grace Hopper and Anita Borg, who made essential contributions to
the industry. Computing was done manually before the advent of electronic computers, and this
tedious job was traditionally assigned to females (Ensmenger, 2012). Computer programmers
were initially glorified clerical workers.

When electronic computers emerged in the United States via the Electronic Numerical
Integrator and Computer (ENIAC) in June 1945, six of the top female “computers” (Ensmenger,
2012, p. 14; the term programmer had not yet been coined) from the Moore School of Electrical
Engineering at the University of Pennsylvania were assigned to work on it. At this time,
engineers did not consider computer software as important as computer hardware. Therefore,
engineers assigned computer programming to females through the mid-1950s. These females
became known as “the ENIAC girls” (p. 35). They were tasked with translating mathematical
formulas into the machine language for the computer. Females were an important part of the
early computer industry, and one estimate puts their participation at 50% during the 1960s. The
desperate need for programmers at the time justified their participation (Ensmenger, 2012).

However, as computer programming became a more lucrative and prestigious career,
females saw their opportunities become limited as computer science became a field that was seen
as more acceptable for males. Ensmenger (2012) and Galpin (2002) suggest this came about
because of the advent of personal computers in the 1980s, but Margolis and Fisher (2002) note
that the decline of women computer programmers actually started in the 1970s before personal
computers were widespread. While this trend occurred in most Western countries, some
countries bucked the trend and kept some level of gender parity in computer science.
Gender Gap in Other Countries

While STEM fields and computer science struggle with increasing representation among females (NGSS Lead States, 2013), the gender gap in computer science appears to be a problem unique to the Western world. Researchers such as Galpin (2002), Gharibyan and Gunsaulus (2006), and Othman and Latih (2006) have found that some countries have near-gender parity in computer science, similar to the situation in the United States in the 1950s. Galpin investigated female participation in undergraduate computer science courses around the world. She did not seek to identify solutions to the gender gap in computer science but simply wanted to look at the data to see where the gender gap in computer science was most prevalent. Her research coincided with the Association for Computing Machinery’s Committee on Women in Computing’s (ACM-W) steps to look at the gender gap on a global scale. The ACM-W created an ambassador program so each country had someone who would report on the status of females in computer science within their country (Galpin et al., 2002).

Galpin (2002) did not analyze the data she compiled other than to state there was a typical range of 10% to 40% of females who constitute undergraduate computer science students. She used national data whenever it was available. However in cases where the countries may not have had a good national dataset for computer science participation, Galpin collected the gender breakdown of computer science students directly from universities. According to Galpin, comparing the data from different countries can be difficult since some of the smaller countries only have one university that offers computer science. Her data indicated that countries such as Malaysia, Thailand, and Guyana had a greater proportion of female computer science undergraduate students than male undergraduate students. While the study did not attempt to
explain why there was a greater proportion of female computer science students, the study was able to show that gender parity is possible in computer science.

Gharibyan and Gunsaulus (2006) conducted a study in Armenia with a 75% participation rate for females in computer science throughout the 1980s and 1990s when the United States never went above 37%. Gharibyan and Gunsaulus used surveys and interviews to determine why Armenia has had such success retaining females in computer science, even with a male-dominated culture. They found that males and females in Armenia think similarly about their career choices. Most want a career that will provide a good living, and computer science is a stable well-paying field. Computer science is also considered more math-oriented than engineering-based.

Othman and Latih (2006) investigated computer science in Malaysia in a manner similar to the study by Gharibyan and Gunsaulus (2006) in Armenia to determine why there was no gender gap in Malaysia. Othman and Latih noted female computer science students did not lack role models at the University of Malaya. The dean of computer science was female, as were three out of four department heads at the time of the study. Sixty-three percent of the faculty lecturers in computer science and 73% of the doctorate holders were female as well. This wealth of female role models at the university could be the reason for the gender parity in Malaysia’s computer science industry. The NGSS note that having good mentors or female role models is a path to gender parity (Scantlebury & Baker, 2007).

The United States and other Western countries have been dealing with a gender gap in computer science since the 1980s, but Malaysia and Armenia had gender parity in computer science during that same time period. It is helpful to see which countries are successfully
recruiting females in computer science and why. While the work by Gharibyan and Gunsaulus (2006), Othman and Latih (2006), and Galpin (2002) did not investigate countries’ success at recruiting females into computer science, it is encouraging to see that it was possible to achieve gender parity in computer science. Gender parity and increased representation of underrepresented groups in STEM are major goals of the NGSS (NGSS Lead States, 2013), so evidence that this parity can be achieved is helpful.

Is Gender Bias Real?

While there is clearly a gender gap in computer science participation in the United States, the question now becomes whether the gap is caused by gender bias or some inherent difference in the genders. The NGSS believes female students are underrepresented in STEM in part because of gender bias (NGSS Lead States, 2013). While there is little research examining gender bias in computer science (Cheryan, Plaut, Davies, & Steele, 2009; Medel & Pournaghshband, 2017), there is a wealth of research investigating gender bias in general or in the sciences.

Steinpreis, Anders, and Ritzke (1999) sent résumés to university faculty to gauge how likely faculty members would be to hire or provide tenure to the person represented by the résumé. The résumés were real, but the names were changed to clearly female or male. Steinpreis et al.’s purpose was to determine if gender was a factor in hiring decisions based on earlier research (Liss, 1975; Morrison & Von Glinow, 1990; Northcraft & Gutek, 1993; O’Leary & Wallston, 1982). Steinpreis et al. (1999) found there was no difference in level of being hired between the genders with a high quality résumé. However, the entry-level résumés did indicate
bias against the female candidate by both males and females. That is, candidates with male names were more likely to be selected than candidates with female names. If this trend holds in computer science, teachers, parents, and counselors may unintentionally oppress female students who do not show immediate talent for computer science by steering them away from a computer science path.

A more recent study by Moss-Racusin, Dovidio, Brescoll, Graham, and Handelsman (2012) investigated gender bias toward students by university faculty. The researchers looked at science faculty given the well-known gender gap in the sciences at the time of their research (Baram-Tsabari & Yarden, 2010). They used a randomized double-blind study in which science faculty were sent application materials from a student with a male or female name. This study was similar to the seminal work by Steinpreis et al. (1999), but instead of looking at resumes of potential faculty, this study looked at student applications. Moss-Racusin et al. used a wide sample of science faculty from around the country and a between-subjects ANOVA to test the significance of the different groups. They found that regardless of the gender of the faculty member, the female’s application was consistently rated lower than the male’s application.

Handley, Brown, Moss-Racusin, and Smith (2015) also looked at gender bias in academia and sought to confirm the hypothesis that faculty in STEM fields are biased against research that shows bias in STEM. They did this through an experiment in which a random sample of the U.S. population and a sample of STEM and non-STEM faculty from a single research university read a fabricated abstract that stated there was gender bias in university STEM fields. The researchers also did an experiment with the same abstract modified to show no
gender bias and found that faculty from STEM fields were more likely to dismiss the results from the study showing gender bias than non-STEM faculty and the general public.

Handley et al.’s (2015) work came at a time when the gender gap in STEM fields, including computer science, had been well-researched (Baram-Tsabari & Yarden, 2010; Beyer, 2014; Cohoon & Aspray, 2006). Handley et al. used social identity theory as the theoretical framework to argue that groups are more likely to go against research if it challenges the superiority of a group they belong to. In this case, STEM faculty were more likely to challenge research that says there is gender bias within STEM faculty. Handley et al. had a large sample size of 205 participants and calculated the effect size using Cohen’s d. This showed the research was statistically significant.

Handley et al.’s (2015) research builds on previous research into gender discrimination showing that many people possess an implicit gender bias (Carneset al., 2012; Gilovich, Griffin, & Kahneman, 2002). If gender bias in computer science is a genuine problem, how early does it start? Tsan et al. (2016) wanted to determine how the gender composition of collaborative groups in an elementary computer science course is related to student achievement. They investigated this research question through a case study in a fifth-grade computer science classroom. The computer science course was an elective at the school. Curriculum is one of the key aspects of the NGSS for increasing gender diversity (NGSS Lead States, 2013). In Handley et al.’s study (2015), the curriculum for the computer science course was collaboratively developed with the classroom teacher who taught the curriculum. The curriculum was used originally for an after-school program for 13 days in the spring of 2014. It was then redesigned to fit the elective course format of 30 days.
Tsan et al. (2016) investigated a single course at a single school with a sample of 55 students. However, only 18 students submitted the project, which was the focus of the study since the class was an elective, and the project was not turned in for a grade. The class also changed over the course of four semesters, as the teacher made revisions and found different ways to select groups. Tsan et al. originally wanted to see how pairing students by gender affected female students in computer science, and it appears there was a similar effect to pairing in math and science. Female-female pairs consistently performed worse than female-male and male-male pairs. Tsan et al. did note a statistically-significant difference between the all-female groups and the groups that contained at least one male, indicating all-female pairs may underperform other student pairs in computer science. However, the small sample size did not lend as much credence to this finding as it would with a much larger sample size. Overall, there were only four all-female groups.

Robinson and Lubienski (2011) found that a gender gap begins to emerge in math as early as first grade. Similar research from Cvencek, Meltzoff, and Greenwald (2011) shows that gender stereotypes regarding math begin to emerge in early elementary school. Tsan et al. (2016) also investigated a potential gender gap in computer science in elementary schools. This is an inherently more difficult task since computer science is not available in most elementary schools, and if it is available, it is often available as an elective. The math gender gap was not a consequence of a difference in talent between the genders (Cvencek et al., 2011), and if adults perceived female students as being worse at math in early elementary school they could be doing the same for computer science (Margolis & Fisher, 2002).
Why Are Females Underrepresented in Computer Science?

Gender bias may be just one of many factors that keeps females from entering computer science. A collection of studies have ruled out potential reasons for females avoiding computer science, including learning styles, computer attitude, and computer anxiety. A wealth of research also examined barriers that might prevent females from majoring in computer science. These studies are presented in the subsequent section.

Reasons Other Than Gender Bias

Studies have been conducted to determine if there are factors other than gender bias that could lead to the lack of female representation in computer science (Cassidy & Eachus, 2002; Kadijevich, 2000; King et al., 2002; Kordaki & Berdousis, 2014; Lau & Yuen, 2010). These studies looked at possible alternatives to gender bias, but no significant barriers other than gender bias were found. This section looks at some of those alternatives, including research showing they do not necessarily constitute a barrier to females entering computer science.

Lau and Yuen’s (2010) study fits into the context of looking for solutions to the gender gap problem in computer science classrooms. Many studies focused on finding ways to get female students into computer science majors and interested in the classes (Alvarado & Dodds, 2010; Margolis & Fisher, 2002; Sanders, 1994). Lau and Yuen’s study focused on the teaching methods in the computer science classroom. The students were enrolled in a voluntary computer science course, which may skew the results since students with certain learning styles may be more attracted to computer science.
Kadijevich (2000) studied over 100 students at a high school in Serbia to evaluate their attitudes toward computers by surveying classes in math and the natural sciences. Kadijevich’s goal was to determine whether female students might have an inherent dislike of computers that might lead to them not entering a computer science program. Kadijevich found that male students had a more positive attitude about computers than female students did, even when the amount of experience they had with computers was the same. Kadijevich also found there were no differences between gender in terms of computer anxiety, which is consistent with other studies’ results (e.g., Cassidy & Eachus, 2002; King et al., 2002). His finding that females had a less positive attitude about computers compared to males is consistent with females’ attitudes changing as they get older. Female students enjoyed computers at an early age at the same rate as male students (King et al., 2002), but Kadijevich showed females’ enjoyment was gone or at least not at the same level as male students by the time they reach high school.

To encourage future studies about computer confidence/anxiety, Cassidy and Eachus (2002) developed a scale to measure computer self-efficacy (CSE) with university students. They used Bandura’s (1977) social cognitive theory as the basis for their ideas on self-efficacy. Cassidy and Eachus’ research is similar to Kadijevich’s (2000) and King et al.’s (2002). Cassidy and Eachus found that male students had greater computer self-efficacy than female students and that experience with computers led to greater self-efficacy with computers, which closely follows Bandura’s findings as well as Kadijevich’s findings. While these results confirmed Kadijevich’s (2000), King et al. (2002) found no difference in computer confidence in elementary students.
King et al. (2002) sought to determine if students of a certain gender or age were more anxious about using computers. They defined anxiety as feeling uncomfortable using computers or not wanting to be seen as having a talent for computers. King et al. used the computer-anxiety index (Simonson, Maurer, Montag-Torardi, & Whitaker, 1987) and the Computer-Opinion Survey (Montag, Simonson, & Maurer, 1984) to test 372 students in grade seven, 314 students in grade nine, and 224 students in grade 11. King et al. set out to clarify the computer anxiety results of previous studies by using a Rasch analysis. King et al. found no difference between the genders according to the computer-anxiety index, but students did become more anxious the older they got. King et al. surmised that older students felt using a computer for school was “uncool” (p. 81), so many did not want to be seen as having a talent for computers. King et al. (2002) provided some clarity to the computer anxiety issue and found gender was not a factor at the elementary grades. Computer anxiety is sometimes cited as a reason females do not go into computer science, so their study is a helpful way of refuting that.

Previous studies of computer anxiety generated mixed results. Some studies found that students with more experience with computers had less anxiety (e.g., Colley, Gale, & Harris, 1994), while other found more computer access led to more anxiety (Goss, 1996; King, 1993; Rosen, Sears, & Weil, 1987). Studies also determined that females had more anxiety about computers than males (Anderson, 1987; Chambers & Clarke, 1987; Okebukola, 1993), while other studies contradicted those results and found that males had more computer anxiety (Lever, Sherrod, & Bransford, 1989; Loyd, Loyd, & Gressard, 1987; Siann, Macleod, Glissov, & Durndell, 1990).
While not specifically focused on computer anxiety, Kordaki and Berdousis (2014) looked at gender differences in university computer science courses. The researchers investigated the types of courses students at a Greek university were signing up for in categories such as theoretical computer science, computer technology and computer systems, general education courses, and software systems. The researchers surmised that the types of courses students chose might be a symptom of their computer anxiety. Female students tended to choose theoretical computer science courses more other than male students. Male students were more likely to choose programming courses.

The previously cited studies all set out to find reasons other than gender bias that led to female students avoiding computer science. Overall, the two most commonly cited reasons, computer anxiety (Anderson, 1987; Chambers & Clarke, 1987; Okebukola, 1993) and different learning styles (Lau & Yuen, 2010), did not show enough evidence of being a major barrier for females entering computer science. With elementary students, there was no difference in computer anxiety (King et al., 2002). However, as they become older, females are more anxious about computers (Cassidy & Eachus, 2002; Kadijevich, 2000). While a study with a small sample size saw that females in computer science classes had different learning styles (Lau & Yuen, 2010), this might speak more to teaching methods than female preference for computer science. As the NGSS asserted (NGSS Lead States, 2013), gender bias appears to be a major barrier to greater female participation in computer science.
Gender Bias Barrier

Learning styles and computer anxiety do not appear to be the main reasons female students avoid computer science. If that is the case, gender parity is the most logical subject to research as a potential reason for female students eschewing a computer science path in high school. One of the seminal works examining gender bias and barrier to female students in computer science was Margolis and Fisher’s (2002) *Unlocking the Clubhouse*, which examined strategies to increase gender parity at Carnegie Mellon University.

Unlocking the Clubhouse

In *Unlocking the Clubhouse*, Margolis and Fisher (2002) laid out a multiyear project to understand and improve the position of females in computer science education at the university level. They explored why females leave computer science to develop ways to increase female participation. Margolis and Fisher conducted over 230 interviews with male and female computer science students at Carnegie Mellon University, one of the top computer science universities in the country. Margolis and Fisher also worked with 240 high school computer science teachers around the United States to enroll and retain more females in their classes. Ultimately, they noted that computing has been seen as a male field from a very early age. Females who do enter a computer science program can sometimes find themselves intimidated by men who have already been programming for years. As one female student noted:

> [Male students] all start reading machine learning books or robotics books or build a little robot or something, and I’m not like that at all. In my free time, I prefer to read a good fiction book or learn how to do photography or something different, whereas that’s their hobby, it’s their work, it’s their one goal. I’m just not like that at all. I don’t dream in code like they do. (p. 5)
Many females in the study shared similar experiences of not focusing on computers during their free time. This shows how easily females in computer science can become disillusioned. Some females may be experiencing imposter syndrome when they compare their computer experience with that of their male colleagues. While it is possible that many of those females did have less experience with programming before college, according to Margolis and Fisher (2002), it could be they were not given the opportunity to use computers at home as often as male students. This may be the result of inadvertent gender bias, as many parents and teachers believe computers are something for males to use. Margolis and Fisher noted that “the women we interviewed had done less hands-on exploration of the computer than the men. They gave fewer accounts of working beside their fathers and more stories of watching from the sidelines” (p. 19). Gender bias may have prevented these students from using the computer at an early age, which can be a major factor affecting females far down the road as Margolis and Fisher noted that a love of computing almost always begins at home.

Margolis and Fisher (2002) also noted a two-year ethnographic study from Schofield (1995) based on a new computerized geometry tutoring system. Schofield’s study did not originally intend to focus on gender but that ended up as a key issue. A number of male students commandeered the computer lab to play computer games during free periods. Any time someone outside the group came into the lab, the group ignored them and the outsiders typically never appeared again. Margolis and Fisher identified the importance of computer games as a gateway to computer science for male students. They also noted that same gateway is not always inviting to female students. Many of the aspects of games that attract males, such as violence and fantasy environments, tend to turn females off to games. In addition, the few female students in
Computer Science 2 classes were made fun of by the male students in the class. None of the female students in Computer Science 2 went on to take Computer Science 3.

Margolis and Fisher (2002) also made an important point that “44% of the women … and nine percent of the men link their interest in computing to other arenas” (p. 53). They identified that computer science can be connected to almost any field, and in many ways computer science as a field is pointless without those connections. Margolis and Fisher contend that females see these broader connections as integral to their enjoyment of computer science.

The stereotype of the computer geek is another factor that can lead to females leaving computer science. While one-third of the interviewed male students felt they differed from the stereotype of a computer geek who talks about computers all the time, more than two-thirds of the female students felt they were different from the stereotype (Margolis & Fisher, 2002). One female student was discouraged by all of the computer talk in social situations:

I’m like, ‘I don’t care! Can’t you people talk about anything but computers?’ And the thing is, some people here are so happy for the fact that they finally have these friends that just talk about computers! It’s like, ‘Hey, we can go out to dinner and talk about computers, and people won’t laugh at us anymore because computers are hip!’ (Margolis & Fisher, 2002, p. 68)

This geek culture may be yet another barrier that either prevents females from entering computer science or preventing them from persisting once they do enter the field.

Erosion of confidence is another issue Margolis and Fisher (2002) investigated at Carnegie Mellon. While computer science grades were nearly identical for the females and males interviewed for their study, females felt much less confident about their work and were more likely to drop out of computer science, as noted by one of the female students:

I’m actually kind of discouraged now. Like I said before, there’s so many other people who know so much more than me, and they’re not even in computer science. I was
talking to this one kid, and... oh my God! He knew more than I do. It was so... humiliating. (Margolis & Fisher, 2002, p. 81)

This erosion of confidence is not unique to computer science, as researchers have noted it at the college level for students in all disciplines (Brainard & Carlin, 1997; Grant, Rajala, Porter, Lawyer, & Fuller, 1997; Sax, 1994; Seymour & Hewitt, 1997). While it is not unique to computer science, it is just one more barrier females must overcome to persist in computer science and, combined with gender bias in computer science, can make it difficult for female students to persist in computer science.

**Misunderstanding Computer Science**

Often female students build an incomplete picture of the computer science field. They may believe a computer science career can lead to social isolation, which can come from a lack of qualified computer science teachers and computer science role models in their life. Without contact with computer science professionals or other computer science role models, female students may be led by others to believe a computer science career is not a good path for a female to take.

Cohoon and Aspray (2006) noted that despite the increase of females in fields such as science, engineering, and math, there had not been a comparable increase in females in computer science. They examined the reasons the female share of computer science degrees had fallen since the 1980s. They rejected the idea there were biological reasons females avoided computer science. They grouped their research into three areas: analyzing females before college, women in post-secondary programs, and females in the information technology industry.
One of Cohoon and Aspray’s (2006) findings was the lack of qualified computer science teachers at the secondary level, in that many secondary computer science teachers do not have a certification in computer science and just pick up the skills as they need them. Some states do not even have a computer science certification program for teachers. Computer science education in secondary schools also tends to be hands-on rather than theoretical, which may hurt students when they encounter more theoretical study in college. Cohoon and Aspray also found that the anomalies of high schools can cause some high-achieving females to avoid computer science classes. Since most computer science classes do not count for honors credit, some females may avoid the challenge to minimize the damage to their grades (Cohoon & Aspray, 2006).

A lack of female role models in computer science is also something that can serve as a barrier for female students entering computer science. With gender bias potentially preventing females from entering the field, it can become a self-fulfilling prophecy as there are not females in the field to encourage younger female students to follow their path. A study by Jepson and Perl (2002) looked at the results of a survey from the Backyard Project, which was founded to encourage females to explore careers in the computer industry. Jepson and Perl wanted to determine what was keeping females from investigating computer science careers. They found the females mentioned there were not enough role models in computer science and the students did not know enough about the computer industry. They also proposed having female instructors for females when they are introduced to computer science, which is a finding confirmed in later studies (e.g., Accenture, 2016; Hoffman & Oreopoulos, 2009).

While Jepson and Perl (2002) wanted to determine why females were not entering computer science careers, Carter (2006) explored why students with an aptitude for computer
science decided not to choose computer science for their major regardless of gender. Carter targeted 836 students in high school calculus and pre-calculus classes. While the schools were not randomly selected (they were selected because they were alums of Carter’s survey administrators), they still represented a reasonable sample. The results showed females wanted a major that was more people-oriented and felt they did not have the experience or knowledge for computer science. These results are comparable to Margolis and Fisher’s (2002) work. Carter also found that all students had an incorrect image of computer science being disconnected from the real world and simply consisting of writing computer code all day in front of a computer. Carter’s findings are similar to Cohoon and Aspray’s (2006) subsequent research that high school computer science teachers are not trained well enough to teach the subject.

A study by Goode (2007) delved deeper into the role of teachers in providing computer science learning opportunities to underrepresented groups such as females, Latinos, and African Americans. Goode interviewed teachers and administrators at three Los Angeles high schools before and after an intervention for computer science teachers provided by UCLA for Los Angeles public teachers. Goode used Fullan’s (1993) work on change agents to identify that computer science teachers should have four core capabilities: personal vision, inquiry, mastery, and collaboration to serve as good ambassadors for their subject. Goode also identified the underrepresented groups in computer science and suggested there must be a better way for teachers to reach them.

Goode (2007) noted that most school districts do not have the capability of the Los Angeles public school system to offer an intervention for computer science teachers. In fact, many districts have, at most, one computer science teacher. Goode determined that there was no
common path for educators to become computer science teachers but pre-service programs should target teachers with computer science experience to grow the potential field of computer science teachers. At the time of her study, only half of the states in America even had computer science certifications. Teachers with business or math certifications taught many computer science classes, and few of those teachers were taught social justice principles to ensure their computer science classrooms were equitable to all groups. Her study confirmed many results from Cohoon and Aspray’s (2006) study.

Building on Goode’s (2007) work, Bock et al. (2013) wanted to look at females as well as minorities in computer science and determine why those groups are underrepresented in the field. They used data from the Taulbee Survey, interviews with high school and college students, and a random survey of college students. They found that the main reason high school and college students did not enter computer science was because they were not interested in the degree. They found that females perceived the degree as being for men, and minorities perceived the degree as being for “geeks and nerds” (p. 144).

Cheryan et al. (2013a) also studied why female students were underrepresented in computer science. They sought to determine if stereotypes of the lives of computer science professionals adversely affected high school females’ image of the computer science field over a long period of time. Cheryan et al. did this by having the females talk to a computer science professional about that professional’s hobbies. The hobbies included both stereotypical videogames, anime, and programming and non-stereotypical hobbies such as playing sports, hanging out with friends, and listening to music. The participants subsequently completed a survey recording their interest in computer science. Two weeks later, the participants were sent
the same survey. The researchers found that females’ perceptions of the computer science field from the professionals who had talked to the stereotypical computer-related hobbies had a negative view of computer science on both surveys, confirming Margolis and Fisher’s (2002) research.

In a similar study, Cheryan, Plaut, Handron, and Hudson (2013) examined how pervasive stereotypes of computer science are. They surveyed undergraduate students at the University of Washington because stereotypes of computer science majors had been shown to have an adverse effect on females pursuing computer science studies (Cheryan et al., 2013a; Margolis & Fisher, 2002). Their results showed that females who had taken a computer science class were less likely to stereotypically view computer science majors than females who had not taken one of those classes.

Beyer (2014) also wanted to determine why females are underrepresented in computer science by looking at multiple variables, while most studies of female interest in computer science focused on one or two variables. Beyer used Eccles, Barber, and Jozefowicz’s (1999) classic model predicting educational choices and found gender differences in computer self-efficacy, stereotypes, interests, values, interpersonal orientation, and personality. She also found that strong instructors were one of the most important variables leading to females persisting with computer science. These findings are consistent with the earlier research of Margolis and Fisher (2002).

One of the most extensive studies on the lack of female representation in computer science occurred in the late 2010s when Google commissioned the Gallup organization to conduct a multiyear study to better understand computer science perceptions, access, and
learning opportunities among female, Latino, and African American students (Google & Gallup, 2016). Students and teachers across the country were interviewed about their feelings regarding computer science. Male students were much more likely to enter computer science than female students. Google and Gallup (2016) found that parents highly value computer science education. Many parents and educators did not necessarily see the diversity problem in computer science as a component of social justice, since they did not perceive the biases inherent in society that drive underrepresented groups away from computer science. However, teachers were more likely than parents to say a lack of exposure to computers is why females are less represented in computer science. A lack of exposure to computers was also one of the findings of the Margolis and Fisher (2002) study.

Google and Gallup (2016) also found some social barriers to computer science education. Female students were less likely than male students to say they learned computer science online (31% vs. 44%) or on their own outside of class (41% vs. 54%). Female students were also less confident they could learn computer science than male students (48% vs. 65%). Female students were also less likely than male students to be told they would be good at computer science by their parents (27% vs. 46%) or teachers (26% vs. 39%). However, 83% of parents of female students who had not yet learned computer science wanted those students to learn computer science in the future. These findings, especially the findings on confidence and computer use outside of class, are consistent with the findings of Margolis and Fisher (2002).
Attempts to Increase Female Participation in Computer Science

Ultimately, the barriers that keep females from pursuing computer science can be overcome (Alvarado & Dodds, 2010; Margolis & Fisher, 2002; Scantlebury & Baker, 2007). This section first looks at Sanders’ (1994) seminal work on increasing gender equity in computer science. This section then takes an extensive look at research on curricula designed to increase gender equity as curriculum was determined by the NGSS to be one of the important areas for increased gender diversity in STEM (NGSS Lead States, 2013).

**Lifting the Barriers by Jo Sanders**

From 1990 to 1993, Jo Sanders (1994) directed the Computer Equity Expert Project. Sanders’ project employed 200 high school educators representing every state in the United States. Half of the educators were computer teachers, while the rest were math or science teachers. The educators applied to Sanders’ project because they had trouble recruiting female students to their advanced math, science, or computer classes. Sanders’s work came at a time when researches and professionals were just noticing the gender equity problem in computer science. While her book contains anecdotal evidence from computer science teachers as opposed to hard research, much of what she says in the book is confirmed by later research. Her book is divided into seven areas detailing different types of strategies and eight areas detailing different types of resources.
Strategies

The strategies in the following sections are taken directly from Sanders’ (1994) book. The heading titles are the categories she established.

Contests and competitions. These strategies focused on competitions and contests meant to encourage interest in computer science. Some of the strategies are specific to math or science, but many apply to computer science. One strategy recommended in Sanders’ (1994) book was to create an all-female programming team to enter local competitions or take female students in small pairs to local competitions. Another strategy was to have females design and judge problems and solutions for programming competitions. One teacher Sanders interviewed encouraged teachers to advocate that programming teams must contain female students. A final strategy was for a high school to host their own programming competition. Given the dearth of high school programming competitions in the 1990s, this was a good strategy to establish a competition for high school computer science students and is still applicable today. The NGSS believed after-school clubs or competitions were an important aspect of gaining gender equity in the science classroom, so these suggestions hold up over time (NGSS Lead States, 2013).

Counselors. School counselors are an essential part of convincing female high school students to try and/or persist in computer science. One of Sanders’s (1994) recommendations for counselors to do this was for counselors to have discussions with females about how they felt they were treated in computer science classes. Females may be more likely to open up to a counselor than a teacher. According to Sanders, when a teacher sees that a female has not signed up for an advanced computer science course, it is important to find out why the female did not sign up. Those reasons may help retain future female students. Counselors could give teachers
specific feedback from students about what they enjoy or do not enjoy about computer science. Another strategy was to go to feeder schools to talk with counselors about why computer science is important. Sanders noted that talking to female students about taking an advanced course even before they have expressed an interest is a proactive strategy. Sanders also proposed that teachers should tell females not to listen to anyone who tells them what their limits are. A final strategy was for teachers to talk to females in their homerooms, or anywhere teachers can interact with students who are not currently taking computer science courses, about the opportunities available in computer science.

Curriculum/instructional practices. While Sanders (1994) named this section “Curriculum,” many of the strategies also involved instructional practices. One of Sanders’ (1994) strategies was to use pair programming in which one student is at the computer, while the other is considered the “navigator” and tells his/her partner at the computer what to type. Instructional strategies such as pair programming fit into the NGSS model of using research-based instructional strategies to increase gender parity (NGSS Lead States, 2013). Using female pairs can help pair programming according to Sanders, although later research by Tsan et al. (2016) showed female pairs may underperform. Sanders (1994) also contended that programming should be emphasized over secretarial computer skills for females. A different strategy involving videogames deemphasized violence and instead focused on creative games incorporated into the curriculum to help elementary students learn. A gender-neutral curriculum is an important way to achieve gender parity according to the NGSS (NGSS Lead States, 2013). Later research by Accenture (2016) confirms this finding. According to Sanders, creating female-only introductory programming classes could be highly successful, but advanced classes
should be co-ed so females are not segregated for very long. This also connects to the NGSS, as building female student confidence can help them persist and a female-only introductory class is meant to build female confidence (NGSS Lead States, 2013). Accenture (2016) and Hoffman and Oreopoulos (2009) agreed with this finding. According to Sanders (1994), teachers should also provide information on computer careers and invite professional female computer scientists to speak to classes. The NGSS states that mentors are important for female persistence (NGSS Lead States, 2013), and research by Cheryan et al. (2013a) found professional females to be incredibly successful in breaking the myth of the computer geeks in female students.

**Scheduling and resource allocation.** As research by Schofield (1995) showed, males can dominate computer lab time. Sanders (1994) suggested paying attention to which students are using open lab time is important. Teachers can use coupons students can redeem for computer lab time or students can sign up for available time slots. Splitting up odd and even days between males and females in the computer lab can also work. Opening the computer lab for after school use is a feasible option for many schools that would make it available for males and females. Preventing male students from dominating open computer lab time is an important way to avoid inadvertent female oppression.

**Spreading the equity word to females (and males).** Holding assemblies or meetings about gender equity could be important to get the word out to females as well as males. Older women could be used as speakers to talk about issues of sexism from past decades. It is important to include males in these events since many may not even realize that they may be contributing to sexism. The NGSS supports this approach as it is important to speak openly about gender bias
among those who are most affected by it as well as those who may perpetrate it (NGSS Lead States, 2013).

**Spreading the word to colleagues.** Teachers may inadvertently perpetrate gender bias (Lather, 1991), so Sanders (1994) noted that it is just as important to spread the word about gender equity to other teachers as it is to students. While most high schools only have one computer science teacher, teachers from other departments could be encouraged to be supportive of females who express an interest in computers. According to Sanders, starting a gender equity team is one way for teachers to spread the word about gender equity. Staff and administration and even school board members, parents, and students should be a part of this team. The team should work together to research and develop strategies for parents and teachers to take to ensure female students are given the same opportunities as male students. Teachers can organize gender equity workshops or conferences to spread the word to teachers outside their district to help increase gender diversity in other schools.

**Teaching techniques.** To help prevent gender bias in their own classrooms, teachers should try to call on females in the classroom just as often as they call on males (Sanders, 1994). Teachers can record a lesson and count the number of times they call on females and males to see how they are doing. Another strategy from Sanders is for teachers to call out sexist behavior when they see it so students become more aware of it. Teachers should refrain from using the term “guys” to refer to females or the classroom as a whole. For teachers who use student helpers in class, female students should be given the same amount of technical responsibilities as male students. According to Sanders, telling females “great job” or “you’re really good at this” can
help boost their self-esteem. Although more modern research (Dweck, 2006) states that teachers should also encourage students to persist when learning becomes difficult.

Resources

The following sections detail resources Sanders (1994) believed were helpful for building gender equity in the computer science classroom. The section headings are categories she used.

**Extracurricular clubs and programs.** While an early section of Sanders’s (1994) book talked about programming competitions, this section talked about other extracurricular activities. One idea was to work with a Girl Scout troop to help females earn computer-related merit badges. A summer computer program just for females is another idea that one of the teachers in Sanders’ program found successful. Finding local summer programs that already exist may be an option as well. The local YWCA might also be willing to host an after-school computer program for females. The NGSS placed great importance on extracurricular activities as a means of achieving gender parity (NGSS Lead States, 2013).

**Field trips.** Sanders (1994) recommended females attend an Expanding Your Horizons conference, a program that continues today. The conference is a one-day symposium for middle school female students to learn about STEM. Volunteers from the STEM community organize hands-on workshops to get the students excited about STEM. Teachers can also take females to visit a college computer science department to give them some perspective about pursuing a computer science education. Visits to companies using computer science to do good in the world are also helpful. Many students feel that a computer science career involves sitting alone in a cubicle typing code. A visit to a company that uses techniques such as pair programming and
code reviews can help break that stereotype and can introduce female students to valuable mentors (Scantlebury & Baker, 2007).

**Fundraising.** Many of the ideas in the Resources section of Sanders’ (1994) book required money, so teachers submitted fundraising ideas. Sanders noted that the American Association of University Women typically provides funds to take females to special events, although it is typically just for college students. This practice continues today. Also, local female clubs may provide money for trips such as visits to a conference like the Expanding Your Horizons conference or trips to a local computer science company. Finally, Perkins’ grants are available for vocational education teachers and can be used for a computer science classroom on items such as Raspberry PIs, robots, or drones.

**Materials.** Sanders (1994) suggests adding gender equity books to the school library and notes that choosing gender-fair materials should occur whenever possible for the classroom, an approach supported by the NGSS (NGSS Lead States, 2013). Staying away from materials that focus too much on male-oriented activities such as videogames is a good place to start. Additionally, the posters on the walls should have a good mix of females and males, and older materials that contain examples or sexism should be shown to females as examples of how things used to be for females.

**Mentoring.** Older female students should serve as mentors for younger females in computer science (Sanders, 1994). Using older females as helpers for summer or after-school programs for younger females is a great way to accomplish this. Former students who are adults in the computer science industry can also serve as mentors. Furthermore, the American Association of University Women can also arrange job shadowing for females interested in
computer science. Strong mentors are one of the three main supports of gender equity according to the NGSS (NGSS Lead States, 2013).

Parents. Sanders (1994) suggested that parents can help with gender equity, as they are usually the major influence on their daughter’s college and career choices. Parents can also inadvertently be a cause of gender bias in the lives of their daughters (Lather, 1991; Margolis & Fisher, 2002). A workshop or panel on gender equity is a great way to engage parents in the subject. A smaller presentation at a PTA meeting and computer instruction courses for parents and their daughters after school are other ways to get parents involved. Parents can also serve as chaperones for field trips or other events such as hackathons.

Policies - school or district. School districts can assist with gender equity by requiring that resource evaluation forms have a gender equity section (Sanders, 1994). Most school districts have a form that teachers must fill out to purchase a resource so a gender equity section can go a long way to ensuring the resources are gender neutral. Resources and curriculum are two of the factors that affects gender equity in the classroom (NGSS Lead States, 2013). Another strategy is to make sure at least one person who is sensitive to gender equity issues should be on the committee that hires new school- or district-level administrators. Administrators can additionally analyze enrollment data from upper-level computer science classes annually to help illuminate any problems as well as successes in terms of gender equity. Sharing that data with teachers can provide insights that teachers might not see such as female students dropping a specific course. Finally, parents or teachers can ask the school board to come up with a specific plan for increasing gender equity or formalizing gender equity as a district goal can help focus teachers and administrators in the district on the issue.
Recruiting females for advanced courses or clubs. Personal invitations for females to take advanced computer science classes can be a great way to encourage them to persist in computer science (Margolis & Fisher, 2002; Sanders, 1994). Recruiting groups of friends or female students from club and sports teams can also help. Individual notes and/or talking to female students individually are useful strategies. Teachers should also turn to student mentors and tutors for recruiting. Similarly, females in computer clubs should be encouraged to bring a friend to meetings to increase the number of potential females in the clubs. Teachers should especially focus all of these efforts in the weeks leading up to course registration.

Summary of Lifting the Barriers

Many strategies suggested by the teachers in Sanders’ (1994) *Lifting the Barriers* have since been substantiated by research. Programming competitions and coding clubs have become more prevalent since Sander’s work (Congressional App Challenge, 2018). Pair programming is a research-based strategy to help students learn programming and the practice has been shown to build confidence in female students (Braught, MacCormick, & Wahls, 2010). A female-only introductory programming course can likewise build female confidence in computer science (Hoffman and Oreopoulos, 2009). Using creative games as opposed to violent videogames for projects can help peak female students interest in computer science (Accenture, 2016). Teachers should also make sure they are equitable in their classrooms and treat female students the same as male students (Lather, 1991; Margolis & Fisher, 2002). Some of these strategies made their way decades later into the Next Generation Science standards (NGSS Lead States, 2013).
Conclusion

Research has established the field of computer science has a gender gap (National Science Foundation, 2015; Zweben & Bizot, 2017) and that gender equity and a lack of exposure to computer science professionals contribute to the drop in females’ interest in computer science as they become older (Handley et al., 2015; Margolis & Fisher, 2002; Moss-Racusin et al., 2012; Sanders, 1994; Steinpreis, et al., 1999; Tsan et al., 2016). Kadijevich (2000) and King et al. (2002) found there was no difference between the genders in terms of computer anxiety, but Kadijevich (2000) also found that females had a less favorable attitude about computers. In addition, Cassidy and Eachus (2002) found that male students had greater computer self-efficacy than female students.

Some ways to solve the gender gap in computer science were proposed: targeted recruitment (Margolis & Fisher, 2002; Sanders, 1994), female-only events (Alvarado & Dodds, 2010; Ericson, et al., 2016; Margolis & Fisher, 2002; Sanders, 1994), advocacy of gender equality (Cohoon & Aspray, 2006; Margolis & Fisher, 2002; Sanders, 1994), and a focus on the social aspects of computer science (Alvarado & Dodds, 2010; Brinkman & Diekman, 2016; Cohoon & Aspray, 2006; College Board, 2016; Goode, 2006; Marcu, et al., 2010; Margolis & Fisher, 2002).

Recent research is starting to demonstrate concrete ways to increase female participation in computer science, but little research focuses on the secondary level where many female students lose interest. While Sanders’ (1994) book detailed strategies computer science teachers could use to increase gender diversity, her work was based on suggestions from teachers and was mainly anecdotal. Computer science teachers in high school need research-based strategies to
help recruit and retain female students. While Sanders’ work is a good place to start, new research is necessary to validate many of the strategies suggested in her book.
CHAPTER 3

METHODOLOGY

The purpose of this study was to investigate practices used by computer science teachers who had a higher than average enrollment of female students in their AP Computer Science classes. The following questions guided this study:

1. What practices do computer science teachers employ who have a higher than average enrollment of female students in their AP courses? Categories of practices include:
   a. Recruitment
   b. Pedagogical
   c. Mentoring
   d. Curricular
   e. Extracurricular

2. How do computer science teachers use those practices to increase female student enrollment in AP Computer Science? When and how often are they employed?

3. Which practices do computer science teachers perceive as most and least influential in increasing female student enrollment in AP Computer Science courses and why?

This chapter is organized into four sections. The research design section details the rationale for using a mixed-method approach for conducting this study. In the participants section, I describe how the computer science teachers were selected. The data collection section includes information about the quantitative and qualitative instruments employed in this study.
Finally, the steps used to analyze the survey and interview data are presented in the data analysis section.

Research Design

This study used a transformative, sequential, mixed methods design in which the quantitative data were used as the basis for the qualitative data (Teddlie & Tashakkori, 2009). A transformative mixed methods study also has a goal of social change (Greene, 2007), so this study sought to highlight the lack of female students in computer science classrooms.

While a sequential transformative study can start with either quantitative or qualitative data (Teddlie & Tashakkori, 2003), this study started with quantitative data and prioritized the qualitative data collection. Without first using quantitative methods to establish a baseline for the average number of female students in computer science classrooms, I would not have been able to determine which AP Computer Science A teachers to select for the qualitative portion of the study. Therefore, a mixed methods approach was necessary, as the study sought to find common practices among computer science teachers with a higher number of female students.

Participants

This section details how the participants were selected for this study. It starts with an overview of how I determined a representative sample of AP Computer Science A teachers. I then detail the recruitment process to find as many participants as possible. Finally, I discuss the consent letter for when the participants agreed to an interview.
Sample

High school AP Computer Science A teachers ages 22 to 70 were the focus of this mixed methods study. The study used convenience sampling (Patton, 2002) to select the initial quantitative participants from the entire population of American AP Computer Science A teachers in the United States. With a U.S. population of roughly 2,100 AP Computer Science teachers (Microsoft, 2012), a confidence level of 95%, a confidence interval of 5%, and a population proportion of 50%, the goal was to recruit at least 325 survey participants (CheckMarket, 2019). Since the survey was sent online, it was possible that AP Computer Science A teachers outside the United States took the survey. I did include one such teacher in my interviews to get his perspective on gender diversity in computer science. However, the goal was to focus on teachers in the United States.

A nested sampling, which takes a smaller sample from a larger sample (Collins, Onwuegbuzie, & Jiao, 2007), was used to select 12 survey respondents to participate in the qualitative portion of the study. Priority was given to participants who had a number of female students in their AP Computer Science A courses that was higher than the average of the survey respondents. The average proportion of female students in AP Computer Science courses for my survey respondents was 25% during the 2018-2019 school year and 23% during the 2017-2018 school year. The standard deviation was calculated for the proportion of female students in each class. The standard deviation was 19% during the 2018-2019 school year and 19% during the 2017-2018 school year. Teachers with a number of female students at least one and a half standard deviations above the mean were given priority for the qualitative portion of this study, which represented classes in the 93rd percentile of those surveyed. While it was not possible to
have all interview participants have that many female students, all of them at least had a higher than average number of female students. I also tried to find geographically diverse schools for the qualitative participants and ended up with three from the East Coast, four from the West Coast, four from the Midwest, and one international teacher. Unfortunately, I was not able to interview a teacher from the South, as those teachers who replied from the South either did not consent to an interview or did not have a high enough proportion of female students. This selection process resulted in 12 AP Computer Science A teachers agreeing to participate in the qualitative portion of the study.

**Recruitment Strategy**

I cast a wide net to recruit from the pool of 2,100 AP Computer Science A teachers for this study. I used three avenues, including a number of Facebook groups, an email list, and a blog because they are an efficient and resourceful way to connect with potential participants (de Leeuw, Hox, & Dillman, 2008).

First, I recruited participants through the Facebook groups titled AP Computer Science A Teachers, APCS A Readers, and Computer Science Educators. The APCS A Readers group is a private group for teachers who grade the AP Computer Science A exam. It is a small group with just over 200 members. I knew a good number were high school AP Computer Science A teachers, so I shared the survey with that group. The Computer Science Educators group has 750+ members. The group is run by high school teacher Alfred Thompson, college teacher Stephen Edwards, and industry professional Jay Michlin. I shared my survey with this group only one time since there was a limited number of high school teachers among the members.
The main Facebook group I used was AP Computer Science A Teachers, which was started by a high school computer science teacher from Texas in June of 2013. There are over 2,000 members as of this writing. The majority of the group members teach AP Computer Science A in the United States, although a few university computer science teachers are also members.

A second recruiting approach I used was an email list. Alfred Thompson is a computer science teacher at Bishop Guertin High School in Nashua, New Hampshire, and a member of the CSTA Board of Directors who sends out a Computer Science Teacher mailing based on his weblog several times a week. The readership of his weekly mailings is in the hundreds, but he also has over 6,500 followers on Twitter where he also broadcasts his Computer Science Teacher posts. Thompson shared my survey on Twitter as well as through his email list. Thompson’s emails typically include his own thoughts about computer science pedagogy, but he also includes links to interesting research and surveys. His emails are usually short, to the point, and target an audience of mainly high school computer science teachers. While emailed surveys can have a low response rate, surveys coming from a trusted source are more likely to receive a response (Whitley & Kite, 2013). As such, people receiving the survey from Thompson may have been more likely to respond than those in my final group.

The final recruitment avenue I pursued was a mailing list provided by Aaron Braskin, an AP Computer Science A teacher in California who formed a group of teachers called the AP Computer Science Collective in an effort to work together to write high-quality free response questions teachers could use in their classrooms. The group was made up of 129 AP Computer Science A teachers from the United States, most of whom were also graders for the AP
Computer Science A exam. I was a part of this group, so Aaron was willing to share the mailing list with me. While there was overlap with the Facebook groups, I do know that at least one of my interview subjects heard about the survey through my direct email. Therefore, I feel the mailing list did serve as a useful resource.

This three-pronged approach to recruiting was used in an attempt to reach the goal of 325 survey participants. However, I was only able to garner 106 responses. While there was most likely overlap among members of the Facebook groups, Alfred Thompson’s Twitter followers, and Aaron Braskin’s mailing list, sending my survey to all three most likely reached a smaller but reasonable number of the country’s AP Computer Science teachers.

**Consent Process**

The consent letter explained what data would be collected and that the data would be anonymous unless the participant consented to be a candidate for the interview portion of this research study. This consent letter was included at the beginning of the survey. Separate consent letters (Appendix A) were sent to interview participants.

**Data Collection**

Due to the mixed methods design of this study, data were collected in two phases. First, quantitative data were collected through an online survey created in Google Forms. Second, after the quantitative data were analyzed, the qualitative phase was completed by 12 AP computer science teachers who consented to participate.
Phase 1: Survey

A simple descriptive approach (Charles, 1989) was used to collect the survey data (Appendix B). The survey was designed to take approximately 20 minutes to complete. I collected the following information through this survey:

- Total number of students taking AP Computer Science during the 2018-2019 school year
- Total number of students who took AP Computer Science during the 2017-2018 school year
- Number of female students taking AP Computer Science during the 2018-2019 school year
- Number of female students who took AP Computer Science during the 2017-2018 school year
- Exam scores of all students on the 2018 AP Computer Science exam
- Exam scores of all female students on the 2018 AP Computer Science exam
- Practices (recruitment, pedagogical, mentoring, curricular, extracurricular) the teacher employs to retain female students
- How influential the teachers think their practices are in retaining female students

In addition, survey participants who were willing to participate in the interviews were asked for their name, school name, and contact information (i.e., phone number and email address).
Establishing Reliability and Validity

The contact information questions were validated through Google Forms so respondents could not accidentally provide incorrect contact information. Google Forms ensures that emails are in the form name@domain.tld where “tld” stands for top-level domain. While this does not guarantee their email address is valid, it does ensure the email address matches the required format. Questions that required numerical responses were also validated through Google Forms by ensuring participants actually provided a numerical response (Stern, 2008).

A prototype of the survey was reviewed by my dissertation chair and two computer science education experts (Ungar & Liebenberg, 2011). Barbara Erickson, who specifically focuses on increasing the number of female students in computer science, was the first expert who looked at my survey. The other expert was Jim Cohoon, who runs workshops to help secondary and community college teachers increase their diversity in computer science. The responses from Erickson as well as Cohoon are included as Appendix C and Appendix D.

The final survey was then sent to all potential participants. A reminder was posted on the AP Computer Science A Teachers Facebook group after three weeks. I had planned to close the survey after four weeks, but I only had approximately 40 responses at that point. So, I posted the survey again to the AP Computer Science A Teachers group for two additional weeks, which raised the number of completed surveys to 50. I posted the survey one last time after nine weeks to reach my final total of 106 responses.
Phase 2: Interviews

Interviews are an integral part of qualitative research and can be used to gather descriptive data using words from the subjects themselves (Bogdan & Biklin, 2003). The interviews in this study were meant to bolster the quantitative data collection and allow for triangulation of the data (Bogdan & Biklin, 2003). While many interviews involve the researcher interviewing a stranger, it is a good idea to build a relationship with the subject either before the interview or at the beginning of the interview (Whyte, 1984).

I interviewed 12 AP Computer Science teachers, and, if needed, I had planned to interview more to reach saturation. However, after completing the interviews, I did not feel that was necessary. Because the AP teachers were located throughout the country and not in close proximity to me, interviews were conducted through FreeConference.com. Using this software allowed me to record what was shared, and the software then transcribed the audio. Upon receiving each transcript, I checked for accuracy against the original recording by listening to each recording at least once and fixing mistakes or omissions found in the transcription.

An informal interview strategy was used to build rapport with the participants (Gill, Stewart, Treasure, & Chadwick, 2008; Hesse-Biber, 2014). I started with general questions about their winter break or how the end of their semester was going. I then asked questions more relevant to my research questions. The interview protocol (Appendix E) was designed to find practices the teachers employed that they believed led to increased female enrollment in their AP Computer Science classrooms. The AP teachers were given an opportunity at the end of the interview to provide any additional information they believed would be helpful to me (Silva,
Healey, Harris, & Van den Broeck, 2015). Most did not have anything to add, but a few gave helpful strategies they use that did not come up from the interview questions.

Table 1 shows how the two data collection methods aligned with the research questions of this study. The survey provided data for one of the three research questions, while the data for the remaining research questions came from the interviews.

Table 1

Research Questions and Data Collection Strategies

<table>
<thead>
<tr>
<th>Survey</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: What practices do computer science teachers employ who have a higher than average enrollment of female students in their AP courses? Categories of practices include • Recruitment • Pedagogical • Mentoring • Curricular • Extracurricular</td>
<td>Q15: Which of the following practices do you employ that you believe help retain female students in your computer science classes? • Recruitment • Pedagogical • Mentoring • Curricular • Extracurricular</td>
</tr>
<tr>
<td>Q3: Have you made a conscious effort to try and recruit and retain females in AP Computer Science?</td>
<td></td>
</tr>
<tr>
<td>Q4: Your AP Computer Science course has more females than a typical AP Computer Science course. What do you attribute that to?</td>
<td></td>
</tr>
<tr>
<td>Q5: Have you used any recruiting to try to recruit females for AP Computer Science? If so, can you go into specifics and when and how you’ve tried to recruit females?</td>
<td></td>
</tr>
<tr>
<td>Q6: Are there any pedagogical practices you’ve employed that you believe help recruit and retain females in AP Computer Science? If so, what are those practices, when do you use them, and how often do you use them?</td>
<td></td>
</tr>
<tr>
<td>Q7: Have you employed mentoring to try to recruit and retain females in AP Computer Science? If so, can you explain the mentoring program?</td>
<td></td>
</tr>
<tr>
<td>Q8: Are there any curricular programs you use to try to recruit and retain females in AP Computer Science? If so, can you explain those programs?</td>
<td></td>
</tr>
</tbody>
</table>

Table continued on next page
| RQ2: How and when are practices used by computer science teachers to increase female student enrollment in AP Computer Science? | Q3: Have you made a conscious effort to try and recruit and retain females in AP Computer Science?  
Q4: Your AP Computer Science course has more females than a typical AP Computer Science course. What do you attribute that to?  
Q5: Have you used any recruiting to try to recruit females for AP Computer Science? If so, can you go into specifics and when and how you’ve tried to recruit females?  
Q6: Are there any pedagogical practices you’ve employed that you believe help recruit and retain females in AP Computer Science? If so, what are those practices, when do you use them, and how often do you use them? | Q16: Which of the following practices do you believe is the MOST influential in retaining female students in your computer science classes?  
•Recruitment  
•Pedagogical  
•Mentoring  
•Curricular  
•Extracurricular  
Q17: Why do you believe your choice above is the MOST influential?  
Q18: Which of the following practices do you believe is the LEAST influential in retaining female students in your computer science classes?  
Q19: Why do you believe your choice above is the LEAST influential? | Q4: Your AP Computer Science course has more females than a typical AP Computer Science course. What do you attribute that to?  
Q10: Do you think your success recruiting and retaining females in AP Computer Science can be replicated? If so, what advice would you give other teachers? |

RQ3: Which practices do computer science teachers perceive as most and least influential in increasing female student enrollment in AP Computer Science courses and why?

Q16: Which of the following practices do you believe is the MOST influential in retaining female students in your computer science classes?

•Recruitment  
•Pedagogical  
•Mentoring  
•Curricular  
•Extracurricular  

Q17: Why do you believe your choice above is the MOST influential?

Q18: Which of the following practices do you believe is the LEAST influential in retaining female students in your computer science classes?

Q19: Why do you believe your choice above is the LEAST influential?
Data Analysis

The quantitative data were analyzed before the qualitative data because of the sequential design of this mixed methods study. Therefore, the process for analyzing the quantitative data is described first, followed by the process used in deconstructing the qualitative data.

**Quantitative Data Analysis**

The survey results were analyzed using descriptive statistics (Holcomb, 2012). Two measures of central tendency were employed. The mean was used to determine the average number of female students taught by each teacher in the sample during the previous and current school years. In 2018-2019, 25% of students in AP Computer Science A classes were female according to my survey result. That number was 23% during the 2017-2018 school year. Only teachers with more female students than the mean were considered for the qualitative portion of this study.

One measure of variability was used in the quantitative analysis. The standard deviation was calculated for the number of female students in each classroom. Teachers with a number of female students at least one and a half standard deviations above the mean were given priority for the qualitative portion of this study, which represented classrooms in the 93rd percentile of those surveyed.
Qualitative Data Analysis

This section discusses the qualitative data analysis used to analyze the results of the 12 interviews. Member checking was used to verify the transcriptions and memoing and coding were used to prepare the transcriptions for analysis.

**Member Checking**

Member checking was utilized to ensure the credibility of the transcriptions. The 12 AP Computer Science A teachers were given the opportunity to review the final transcriptions for accuracy. I emailed the transcripts to the participants and asked them to let me know if they would like to add any new information or clarify anything they originally shared. They were also asked to make any additions or corrections in the margins of the transcript. None of the interview subjects asked for any additions or corrections.

**Memoing and Coding**

After the interviews were transcribed, memoing was employed to take notes on the transcripts and ask questions about the teachers’ responses (Creswell, 2013). The memos attempted to capture themes prevalent in each interview. After the initial memoing, I developed codes and attached those codes to the transcripts. Open codes (Creswell, 2013) were developed on the first read of the transcriptions based on early thoughts about potential codes. Some of the open codes I developed included math teacher, recruiting, pair-programming, open-ended projects, and real-world projects. After a second read through, the codes were focused and combined through axial coding (Corbin & Strauss, 2008). The main axial codes I developed were
recruiting, pedagogical, mentoring, curricular, extracurricular, and the teacher. The full list of open and axial codes can be seen in Appendix F.

Chapter Summary

A transformative sequential mixed methods design was used for this study. Quantitative data were collected through an online survey, while qualitative data were collected through interviews of a group of participants selected from the quantitative results using nested sampling. The analysis provided rich data from both the survey respondents and the interview subjects. Chapter 4 describes the participants and reports on the findings.
CHAPTER 4
FINDINGS

This chapter details the study’s findings that sought to answer the following three research questions:

1. What practices do computer science teachers employ who have a higher than average enrollment of female students in their AP courses? Categories of practices include:
   a. Recruitment
   b. Pedagogical
   c. Mentoring
   d. Curricular
   e. Extracurricular

2. How do computer science teachers use those practices to increase female student enrollment in AP Computer Science? When and how often are they employed?

3. Which practices do computer science teachers perceive as most and least influential in increasing female student enrollment in AP Computer Science courses and why?

The first section of this chapter presents information about the AP Computer Science teachers who completed the survey (quantitative portion of the study), followed by detailed descriptions of the 12 participants who were interviewed during the qualitative portion of the study. The second section of this chapter combines the findings to answer Research Questions 1 and 2, and the final section details the results for Research Question 3.
Participants

Survey Respondents

The survey collector was open for two months (September to November 2018), resulting in 106 AP Computer Science teachers completing the instrument from all regions of the United States as well as one international teacher from Canada and another from Colombia. Of those respondents, 59 were female and 47 were male. The survey data also revealed they had been teaching AP Computer Science A for an average of seven years. Additionally, two respondents had all-female AP Computer Science A classes, and one of those teachers taught at an all-female school. In contrast, 16 survey respondents had no female students in their AP Computer Science A courses. Collectively, the teachers had an average female student population of 24% in their AP Computer Science A classes.

From the pool of survey respondents, 12 were chosen to participate in the online interviews. Criteria for selection included a higher-than-average percentage of female students in their AP Computer Science A classes. The average percentage of female students in AP Computer Science A classes of all survey respondents was 23% in 2017-2018 and 25% during 2018-2019. As an example, in 2017-2018, if one computer science teacher had five female students in a class of ten (50%) and another teacher had five female students in a class of 25 (20%), the first teacher would be considered for an interview while the second teacher would not. The interview participants had an above average number of female participants in 2017-2018 (27%), and a well above average number of female students (41%) the following school year. This is mainly attributed to two teachers (Hopper and Lamarr) who had large increases in
their proportion of female students from 2017-2018 to 2018-2019, but all of the teachers chosen had an above average number of female students during the second year.

Table 2 provides demographic information about the interview participants. Pseudonyms were chosen based on famous figures in computer science history.

What follows is background information about each of the interview participants: 1) total years of teaching experience, 2) number of years teaching AP Computer Science A, 3) percentage of female students in their AP Computer Science A during the 2017-2018 and 2018-2019 school years, and 4) demographic information about the school. Each description is presented as a vignette.

**Anima Anandkumar**

Anima Anandkumar has been teaching AP Computer Science A for the past three years at a small private pre-K through secondary school on the west coast. Anandkumar has a Bachelor’s and Master’s in Computer Science and worked in the software industry for 15 years. After she was laid off from her software position, she decided to go into teaching since her husband was a teacher, and she wanted to work closer to home. She does not hold a teaching license, but she has been teaching for the past four years – three years of teaching AP Computer Science A.

In the 2017-2018 school year, Anandkumar had seven female students in a class of 17 AP Computer Science A students, representing 41% of the class. In 2018-2019, her percentage of female students was 40% with four female students out of 10. Anandkumar believes pedagogy is the most important practice to retaining females in computer science and the curriculum is least important.
Table 2

Interview Participant Quick Reference

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Years in APCS</th>
<th>% of Female Students in 2017-2018</th>
<th>% of Female Students in 2018-2019</th>
<th>School Information</th>
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<td>Female</td>
<td>3</td>
<td>41%</td>
<td>40%</td>
<td>Private School</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pre-K - High School</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~150 High School Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>West Coast</td>
</tr>
<tr>
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<td>Female</td>
<td>6</td>
<td>36%</td>
<td>32%</td>
<td>Public High School</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~2000 Students</td>
</tr>
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<td></td>
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<td></td>
<td></td>
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<td>Suburban West Coast</td>
</tr>
<tr>
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<td>18</td>
<td>25%</td>
<td>33%</td>
<td>Public High School</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~2000 Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Suburban Midwest</td>
</tr>
<tr>
<td>Grace Hopper</td>
<td>Female</td>
<td>2</td>
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<td>47%</td>
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<tr>
<td></td>
<td></td>
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<td>~1400 Students</td>
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<tr>
<td>Mary Kenneth Keller</td>
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<td>10</td>
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<td>33%</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~1200 Students</td>
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<td>Suburban Northeast</td>
</tr>
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<table>
<thead>
<tr>
<th>Name</th>
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<th>Age</th>
<th>Percentile 1</th>
<th>Percentile 2</th>
<th>Education Level</th>
<th>School Type</th>
<th>School Size</th>
<th>Location</th>
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<tbody>
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<td>33%</td>
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<td>Private School</td>
<td>Pre-K - High School</td>
<td>~365 High School Students</td>
<td>South America</td>
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<td>Female</td>
<td>2</td>
<td>9%</td>
<td>65%</td>
<td>Public High School</td>
<td>~1300 Students</td>
<td>Suburban Northeast</td>
<td></td>
</tr>
<tr>
<td>Ada Lovelace</td>
<td>Female</td>
<td>3</td>
<td>33%</td>
<td>37%</td>
<td>Private School</td>
<td>~1300 Students</td>
<td>Suburban Midwest</td>
<td></td>
</tr>
<tr>
<td>Ken Thompson</td>
<td>Male</td>
<td>5</td>
<td>20%</td>
<td>35%</td>
<td>Private College Prep</td>
<td>~400 Students</td>
<td>Suburban West Coast</td>
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<tr>
<td>Alan Turing</td>
<td>Male</td>
<td>9</td>
<td>37%</td>
<td>38%</td>
<td>Public College Prep</td>
<td>~1800 High School Students</td>
<td>Urban Midwest</td>
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<tr>
<td>John von Neumann</td>
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<td>25%</td>
<td>31%</td>
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<td>Sophie Wilson</td>
<td>Female</td>
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<td>27%</td>
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<td>Private College Prep</td>
<td>~250 High School Students</td>
<td>Urban Midwest</td>
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</table>
Anita Borg

Anita Borg has been teaching AP Computer Science A for the past six years at a suburban west coast school with an enrollment of 2,000 students. Borg attempted to complete a computer science major in college but was intimidated by the only curricular path her school provided, so she chose to learn a few programming skills. She started her career in graphic design but eventually started doing freelance programming using the Javascript and AppleScript programming languages. Borg became bored with her freelance work, so she decided to go into education and began teaching high school math classes. Her principal wanted her to teach some computer science classes; however, that did not interest Borg. After a major tech company gave her school some money to teach a programming course, Borg was assigned to teach the new prep. She ended up enjoying the course, then teamed up with Teals, a program for computer science professionals who co-teach a computer science course with a high school teacher for one or two years. After two years of working with Teals, Borg began to teach more computer science courses. At the time of this study, she had been teaching AP Computer Science A for six years.

In the 2017-2018 school year, Borg had 32 female students in AP Computer Science out of the 89 enrolled (36%). In 2018-2019, her percentage of female students dropped slightly to 32% (i.e., 30 out of 93 total students). Borg believes pedagogy is the most important practice to retaining females in computer science with mentoring being the least important practice.
Betty Holberton

Betty Holberton has been teaching AP Computer Science A for 18 years at a public high school in the suburbs of Chicago with an enrollment of approximately 2,000 students. Holberton always wanted to be a teacher, but her high school guidance counselor convinced her to choose a career path other than teaching. Holberton went to college and majored in math. She worked at a large technology company for 13 years before working as a consultant and trainer for computer programmers. She finally decided to go into teaching and earned her teaching license. She has been teaching math and computer science for the past 18 years.

In the 2017-2018 school year, Holberton had eight females out of 32 AP Computer Science A students (25%). In 2018-2019, her percentage of female students rose to 33% (12 out of 36). Holberton believes pedagogy is the most important practice to retaining females in computer science with mentoring being the least important practice.

Grace Hopper

Grace Hopper started as a math teacher at a Northeast suburban public high school. When her school added AP Computer Science Principles, she started teaching that course as well. During the 2017-2018 school year, Hopper’s school added AP Computer Science A. She has been teaching the course ever since.

During the 2017-2018 school year, Hopper had one girl out of the 17 enrolled AP Computer Science A students. However, in 2018-2019, that number grew to eight females (an increase from 6% to 47%). Hopper felt recruiting was the most important practice to retaining females in computer science with curriculum being the least important.
Mary Kenneth Keller

Mary Kenneth Keller has been teaching AP Computer Science A for 10 years. She teaches at a suburban public high school in the Northeast with an enrollment of approximately 1,200 students. She was a math major in college but took a number of computer science courses. After college, she worked as an analyst at a large financial firm. While in that position she worked closely with the technology department as financial transactions began to move online. Keller went on to earn a master’s degree before starting a Ph.D. in a field called Operations Research (i.e., a degree program that combines math, computer science, and statistics). While working on her that degree, Keller realized she did not want to stay with the financial firm and switched to a Master’s in Education. Her teaching career began as a math teacher, which included a computer applications class. After the AP Computer Science A teacher moved into an administrative position, Keller was asked to teach the course, which she has taught on-and-off since 2000.

During the 2017-2018 school year, Keller had 11 female students out of 38 AP Computer Science A enrolled students (29%). In 2018-2019, her enrolled female students rose to 33% (i.e., 19 out of 58 total students). Keller perceived recruiting as the most important practice to retaining females in computer science with extracurricular activities as least important.

Donald Knuth

Donald Knuth teaches AP Computer Science A at a PreK-12 private school. Knuth started out in engineering, but education was always of interest to him because both of his parents were teachers. When there was an opening for a computer science teacher in Columbia,
he jumped at the opportunity. He has been teaching AP Computer Science A for the past three years.

Knuth had four females enrolled out of 12 AP Computer Science A students during the 2017-2018 school year (i.e., 33%). That percentage rose to 50% (i.e., 10 out of 20 students) in 2018-2019. For Knuth, pedagogy was the most important practice to retaining females in computer science. Extracurricular activities were the least important.

Hedy Lamarr

Hedy Lamarr teaches at a public, suburban high school located in the Northeast that has roughly 1,300 students. Lamarr switched to her current school after nine years of teaching math in another district. When the computer science teacher left, Lamarr was asked to teach computer science, even though she had no background. For the past two years, she has been teaching AP Computer Science A.

During the 2017-2018 school year, Lamarr reported 9% of her AP Computer Science A students were female (3 out of 32). That percentage jumped significantly in 2018-2019 to 65% (55 females out of 88 total students). The most important practice for Lamarr was recruiting. Curriculum was least important for her.

Ada Lovelace

Ada Lovelace has been teaching math and computer science at a private Catholic high school in the suburbs of Chicago for the past six years. She earned her undergraduate degree in mechanical engineering and worked in an engineering occupation for almost 10 years. After having children, Lovelace stayed home for a few years. It was during this time that she developed an interest in teaching. She went back to school for her master’s and teaching
certificate and got her first job on the condition that she would also teach some computer science classes. Lovelace only had one computer science course while in college, so the school paid for her to learn the basics of computer science. She, in turn, started to teach courses in the C++ and Java programming languages. Eventually, Lovelace developed an AP Computer Science A course, which she has taught for the past three years.

Lovelace had three females out of the nine students in her 2017-2018 AP Computer Science A course (33%). That percentage grew a little higher during the 2018-2019 school year to 37% (7 out of 19 total students). The most important practice for Lovelace was recruitment, with curriculum as least important.

**Ken Thompson**

Ken Thompson teaches at a suburban, private college preparatory school on the west coast. There are roughly 400 students at his school. Thompson initially majored in computer science in college but switched to geology. After graduation he accepted a job teaching computer classes at a small Catholic school. In 2009, Thompson moved to his current school where they asked him to start their computer program. He has taught AP Computer Science A for the past five years.

Thompson’s female enrollments grew from 20% to 35% across the two school years (i.e., 2017-2019). Unlike many of those interviewed, Thompson felt that curriculum was the most important practice to retaining females in computer science. He identified pedagogy as least important.
Alan Turing

Alan Turing has been teaching AP Computer Science A for nine years at a public school in the Midwest. Turing has a Ph.D. in math and 15 years of college teaching experience. He helped develop a math minor for a college in the Northeast and worked as an independent consultant while working on software grading programs for teachers. After moving to his current city, Turing worked as a programmer for a short time and then as a data architect for 10 years at a medical center. After making connections at a local high school, Turing was able to get a job teaching computer science in a school that had struggled to run an AP Computer Science A course.

Across the two academic school years, Turing’s female enrollments were 37% and 38%, respectively. For him, the most important practice to retaining females in computer science entails pedagogy. He perceived curriculum as least important.

John von Neumann

John von Neumann teaches AP Computer Science A at a suburban, west coast public school in a town that is home to a major international tech company. von Neumann grew up with computers and always had an interest in programming and computer science. von Neumann went to college as a math major but decided to minor in computer science because of personal interest. von Neumann spent the first eight years of his career teaching math, but his students’ parents began demanding computer science classes. In response to their request, he started teaching AP Computer Science A along with other computer science courses. He is a seasoned computer science teacher with 14 years of experience. During the 2017-2018 school year, von Neumann reported that 24 out of his 97 AP Computer Science students were female (25%). In 2018-2019,
that percentage rose to 31% (30 out of his 98 total students). von Neumann believes mentoring is the most important practice to retaining females in computer science with curriculum being least important.

**Sophie Wilson**

Sophie Wilson has taught AP Computer Science A for the past four years at a small, private, college-prep school located in a major Midwestern city not far from a college with a world-renowned computer science program. Wilson studied chemical engineering in college, and while doing so, she worked at a summer camp with her high school chemistry teacher. Wilson decided she really enjoyed teaching, and when she graduated from college, her chemistry teacher alerted her to a computer science opening at her school. Wilson teaches computer science, along with chemistry at her current school.

During the 2017-2018 school year, Wilson had four females out of 15 AP Computer Science A students, representing 27% of those enrolled. That percentage jumped to 42% during the 2018-2019 academic year when eight of her 18 enrolled students were female. The most important practice for retaining females for Wilson was curriculum. She perceived pedagogy as least important to retention.

**Findings**

The next sections focus on the outcomes of the research questions. I combined the qualitative and qualitative findings to provide detailed results.
Research Questions 1 and 2

The first research question was “What practices do computer science teachers who have a higher than average enrollment of female students in their AP courses employ?” This question sought to categorize teachers’ practices into the following categories: recruitment, pedagogical, mentoring, curricular, and extracurricular. The second research question was “How do computer science teachers use those practices to increase female student enrollment in AP Computer Science?” Although both research questions are similar, the main difference is the second question sought to determine practices specific to increasing female enrollment. Combining practices helped contrast those the teachers generally implemented with those they used to recruit females. As a result, I purposefully organized the findings for Research Questions 1 and 2 by classroom practices, utilizing data from both the teacher surveys and interviews (Table 3). A detailed explanation of the five major themes and their associated subthemes are detailed in the sections that follow.

Extracurricular Practices

Sixty-nine total responses, including 55 out of 102 responses to the survey (54%) and 14 separate comments in the 12 interviews, formed the first theme: extracurricular practices. The NGSS claimed extracurricular practices were one approach for increasing gender diversity in STEM fields (NGSS Lead States, 2013). The teachers discussed a number of extracurricular programs at their schools they believed might influence female enrollments. Of the teachers who had higher than average female student enrollment in their AP Computer Science A classes during the 2018-2019 school year, four of the 12 (Borg, Holberton, Hopper, and von Neumann)
used extracurricular programs as a way to enroll and retain female students in computer science. Most of the teachers had local chapters of national programs at their schools; however, a few created their own programs. Many teachers looking to increase the number of female students in their computer science classes utilized female-only programs to do so, while others tried to recruit through coed extracurricular programs. Two subthemes emerged from this larger theme: national programs and female-only programs.

Table 3

Research Questions 1 and 2 Themes and Subthemes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Subtheme</th>
<th># of Survey Comments</th>
<th># of Interview Comments</th>
<th>Total # of Comments</th>
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<tr>
<td>Extracurricular Practices</td>
<td><em>National Programs</em></td>
<td>30</td>
<td>7</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td><em>Female-Only Programs</em></td>
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<td>7</td>
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</tr>
<tr>
<td>Recruitment Practices</td>
<td><em>Recruiting During School</em></td>
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<tr>
<td></td>
<td><em>Recruiting in Groups</em></td>
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</tr>
<tr>
<td></td>
<td><em>Recruiting from Younger Grades</em></td>
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<tr>
<td>Curricular Practices</td>
<td><em>Creative Projects</em></td>
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<td></td>
<td><em>Real-World Projects</em></td>
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<tr>
<td>Pedagogical Practices</td>
<td><em>Pair Programming</em></td>
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<tr>
<td>Mentoring Practices</td>
<td><em>Role Models</em></td>
<td>6</td>
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<tr>
<td></td>
<td><em>Classroom Community</em></td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>
There are a number of national programs dedicated to engaging students in computer science. Some programs focus on a specific subset of students such as Black Girls Code or the LEAD Computer Science Institute Program designed for underrepresented high school students. Other programs target students interested in computer science such as the Technology Student Association (TSA) and robotics competitions like FIRST Robotics and VEX Robotics. Thirty survey respondents mentioned in their free-form comments the name of a national program dedicated to computer science. Seven of the interview subjects mentioned that their school hosts a national program dedicated to computer science. The following paragraphs detail the national programs mentioned by the interview and survey participants.

Twelve survey respondents said their schools offer competitive robotics teams. Over half of the interviewed teachers (Anandkumar, Borg, Lovelace, Hopper, Thompson, Turing, and Wilson) mentioned robotics teams, but none stated they resulted in a large number of female participants. Borg had the most female participants on her school’s FIRST Robotics team, but she estimated they comprised only 10% of the participants.

Eighteen survey respondents mentioned the national organization Girls Who Code. Of the interview participants, Borg, Hopper, von Neumann, and Turing all mentioned that they provide Girls Who Code programs. Hopper specifically felt the program not only helped improve the perception of computer science but also served her well as a recruiting tool. “If they joined [Girls Who Code]…[I’ll say], ‘If you like, this maybe you should think about taking [a computer science] class as well’” (interview, December 18, 2018). Hopper saw Girls Who Code as a valued opportunity to talk about her computer science classes. A survey respondent echoed
Hopper’s belief that the program, Girls Who Code, increases the perception of computer science: “My Girls Who Code club gets the girls interested in CS and gives them some confidence prior to taking AP CSA” (survey response, October 17, 2018). Of the seven survey respondents who wrote comments about Girls Who Code, three mentioned the program built confidence, and all seven mentioned using the program as a way to recruit more female students.

Hopper and one survey participant mentioned another program: Technovation. The female-only program includes a prescribed curriculum focused on creating and marketing an app. Additionally, the program is designed to encourage female students to investigate careers in computer science or business. Hopper used the program as a recruiting tool, but she was finding more business students than computer students joined the program. The survey respondent also used the Technovation program (in combination with Girls Who Code) as a means for recruiting female students to take computer science courses.

Hopper mentioned using her program as a recruiting tool, but many teachers found that the time commitment, for both teachers and students, can make extracurricular clubs difficult to implement. One teacher in the survey stated that “our students’ extracurricular calendars are so full already with their academic course load, other academic clubs, and sports, it is very difficult to get them to introduce yet another thing into their schedules outside of class time” (survey response, October 24, 2018). Another teacher from a school in the suburbs of Chicago stated, “I wish I had the opportunity to start an extracurricular, but I have time restraints preventing it” (survey response, October 19, 2018). The first teacher found that many students are involved in multiple activities, which limits their opportunities to participate in an extracurricular club dedicated to computer science. The second teacher had restrictions on his own time. He was
already heavily involved in coaching and did not have the time to dedicate to an after-school club to drive female interest in computer science.

**Female-Only Programs**

One survey respondent from a public high school in Virginia emphasized female-only programs as key to increasing female enrollment in computer science, an approach the NGSS claimed could help increase female interest in STEM (NGSS Lead States, 2013).

“If it is not a strong club that is exclusively for women, then I think it is very easy for the club to be dominated by boys, or be dominated by those who already have a background in the subject, which prevents newcomers from joining in. For example, our Robotics team tends to have mostly people who have been doing it since elementary / middle school. Occasionally there are newcomers, but the ones that excel tend to be the ones who have been doing it a long time. (survey response, October 14, 2018)

This survey respondent believed female students are not as comfortable in situations when they are in the minority. Holbertson echoed this response in her interview when she said, “My hope is that the camaraderie of that club [will mean] having more girls in the classes” (interview, December 26, 2018). This sentiment is similar to what teachers said about Girls Who Code and how it can be a way to help female students work in a more comfortable environment as well as see computer science in a different light.

While many of the teachers used female-only clubs at their schools, a few created their own female-only programing groups. For example, Lovelace developed a club called “Fem in STEM,” von Neumann led a program called “Women in Technology,” Wilson sponsored a club called “Steminists,” and Holberton created a club without a catchy title. All of these clubs involved programming, but Fem in STEM and Steminists tried to encourage females to go into STEM fields in general. Wilson described the purpose of her self-created club:
It’s about increasing the inclusion of minorities in STEM fields and in STEM classes, and it's definitely something that has helped because [you have] a group of girls behind you saying ‘You can take AP Computer Science. I took AP Computer Science and did well.’ (interview, December 13, 2018)

Wilson not only articulated that she dedicated her female-only club to including more minorities in STEM fields, but she also believed it helped her recruit more female students for AP Computer Science A.

Not all participants in this study saw gender-segregated programs as a good thing. Even though his school offered a Girls Who Code club, Turing did not believe in the idea. He emphatically stated, “I would never create a female-only club. I do not think that’s appropriate either. I don’t think teachers should wall off opportunities to people for reasons other than interest” (interview, December 17, 2018). A survey respondent from a private college preparatory school in the Northeast responded similarly: “I do not actively attract ladies; I similarly do not dissuade gentlemen…in our school all are treated equally” (survey response, October 8, 2018). Both the survey respondent and Turing expressed that having a club open to anyone is the better approach because a female-only program limits opportunities for other students.

**Recruitment Practices**

The second major theme focused on teachers using a variety of recruitment practices in their computer science classrooms (32 total comments). Of the teachers who had a higher than average female student enrollment in their AP Computer Science A classes during the 2018-2019 school year, 41 out of 50 (82%) felt recruitment helped with enrollment and retention of the female students. While the NGSS did not directly address recruiting (NGSS Lead States, 2013), according to the surveyed teachers it was important to increasing gender diversity. Three
subthemes emerged from this larger theme: recruiting during school, recruiting in groups, and recruiting from younger grades.

**Recruiting during School**

The first subtheme included visiting other classes and attending school events to recruit students (13 total responses). Hopper, for instance, described:

> talking to the students personally about taking computer classes helps and students you have a relationship with helps a lot…they trust you and you're almost like a guidance counselor where you're saying, “Hey, I really think that you should take this course.”

(interview, December 18, 2018)

For Hopper, making a personal connection with students made a big difference when recruiting. The key was finding a way to talk to them. Like Hopper, Lamarr also talked to students about the importance of computer science. During her own math classes, Lamarr showed her students an engaging video and completed some live coding with them to demonstrate how a small amount of code could create something interesting. Another recruitment strategy Lamarr used included going to other classrooms. She explained her approach: “I had a sub the whole day…and I went into the [pre-calculus] classes and talked to them, showed them a little video to get their interest, and did some live coding with them” (interview, December 12, 2018). Similar to Lamarr, a survey respondent from a suburban Virginia high school also used his own math classes to recruit students for his computer science classes.

> I recruit students from Pre-AP / Honors math classes by doing Hour of Code with these classes, and then talking briefly about my intro computer science class, and the reasons why computer science is so important to many professions other than IT. (survey response, October 14, 2018)

> He used a program called the Hour of Code, which is typically held during Computer Science Education Week in December. Participants spend an hour learning to program, typically
using drag-and-drop commands featuring popular characters from *Star Wars, Frozen*, or other sources. Three other survey respondents said they used the Hour of Code to recruit; however, they noted it can be difficult to get in front of students to talk to them about computer science.

Teachers such as Lamarr had built-in recruiting groups because they taught classes other than computer science. Of the 12 interviewed teachers, six (50%: Anandkumar, Hopper, Keller, Lamarr, Lovelace, and Turing) also taught math courses. Borg used to teach math courses in addition to computer courses until her computer courses became too popular for her to teach both subjects. Borg’s situation shows one of the drawbacks of teachers using their own classes to recruit.

Even though Anandkumar could recruit students from her own math classes, she took a slightly different approach compared to Lamarr. She recruited students when serving as a substitute for other teachers. At her school, the substitute policy required teachers to fill in when other teachers were absent. While subbing, Anandkumar purposely recruited students, especially those she did not normally see. Also, because she taught at a small, private, it made it easier to get to know students.

I know [students] from school events, some of them just because they're siblings of students, and I think most of the ones that I talked to I had never had in class before. I know that they are good students, and they just haven’t had the opportunity [to take my classes]. (interview, December 18, 2018)

Anandkumar used subbing opportunities to recruit female students she did not normally see. Another advantage of teaching and substituting at this small school meant that Anandkumar had the advantage of connecting with students even before they entered high school.

Hopper took a completely different approach than Borg and others. Hopper talked about sending her current students letters and emails about taking AP Computer Science A. She also
talked to parents about their students taking the course. Hopper thought these approaches were helpful for getting students she might not otherwise have contact with interested in computer science: “sending a note home or emailing students or catching parents on parents night and just kind of putting the buzz in their ear” (interview, December 18, 2018). That personal contact with students as well as parents seemed to be important to Hopper’s recruitment strategy. A survey respondent had a similar response.

My recruitment involves letters home and conversations with parents as well as students. Parents have a huge influence on the courses students choose at my school, especially AP courses. Letting them know that their child is capable and getting them to understand the benefits of the course helps get them on my side. (survey response, November 12, 2018)

Hopper and this survey respondent agreed that contact with students as well as their parents helped with recruiting. A letter telling students they were welcome to enroll was a helpful tool in convincing students they could succeed in computer science.

In contrast to Hopper, Keller taught at a high school with an enrollment of 1,500 students. For her, it was more challenging to establish connections with students outside the classroom for two key reasons. First, the size of the school made it difficult. Second, Keller taught at a county academy, and the students came from different schools throughout the county. However, similar to Hopper, Keller capitalized on opportunities to talk with parents to recruit their children to her computer classes. For example, she always attended her school’s “AP and Elective Fair.” She strategically recruited current students to talk with parents. Keller also leveraged peers talking with peers. Her perspective was that students, in particular females, felt more comfortable asking questions of a peer about computer science courses, as opposed to the teacher. As she described,

Our school district a couple of years ago decided to create an AP and Elective Fair prior to scheduling time…I personally get students to come and run my table because I feel like the students talk to other students that you’re going to recruit. I usually get a lot of
girls who will volunteer at the table as well as boys, but they will talk to students, disseminate information, will do demos of some of the code that we do, and I think that's one of the avenues that students get interested. (interview, December 22, 2018)

The administration at Keller’s school gave teachers broad discretion to market their classes at the Elective Fair, where tables were set up in the gymnasium for teachers to promote their classes. In her opinion, hearing a recommendation to take a computer class from a peer held more value than a recommendation from the teacher.

Four teachers in the survey mentioned sending recruitment letters to students as a way to contact students they may not necessarily be able to see during the school day. One teacher noted that he sends a recruitment letter to parents as well as students.

My recruitment involves letters home and conversations with parents as well as students. Parents have a huge influence on the courses students choose at my school, especially AP courses. Letting them know that their child is capable and getting them to understand the benefits of the course helps get them on my side. (survey response, November 12, 2018)

This teacher believed that parents have a large influence on the courses students choose in high school, so he was determined to reach out to them via recruitment letters. Some teachers who do not have access to students outside of their computer classes reach out to teachers of other subjects to determine students to target with recruiting. A Wisconsin teacher talked to the math teachers in his school to find female students who might be good computer science students. He sent recruitment letters to those students as well as their parents. By using the mail merge feature of popular word processing software to create these letters, these teachers were able to create personalized letters without using an exorbitant amount of their free time.

While Anandkumar, Keller, and other teachers reported they purposely recruited female students, three of the 12 teachers interviewed (25%) indicated they did not. Thompson, Borg, and von Neumann all felt their recruitment strategies helped female enrollments simply by
happenstance. In fact, Thompson’s school discouraged active recruiting. When he did have a rare chance to talk with students, the focus was on all students, not just females. Borg differed in her approach: “I perhaps work a little harder with the girls who sometimes are more worried about taking a computer science class” (interview, December 27, 2018). However, she believed in recruiting everyone equally. When I asked von Neumann if he made a conscious effort to recruit female students, he responded, “Yes and no. The answer is yes but I did more of that five or six years ago” (interview, January 11, 2019). It is notable that von Neumann mentioned he had done more recruiting of females in the past, but he stopped doing so because those efforts did not provide the results he had hoped for.

**Recruiting in Groups**

A total of 13 responses came from the survey and interviews to substantiate this second subtheme. The NGSS also identified that social groups, even if they are not directly related to STEM, can be a key avenue for increasing gender diversity in STEM (NGSS Lead States, 2013). Lamarr, Anandkumar, and Keller mentioned they sought out groups of female students as part of their recruitment efforts. As previously discussed, Lamarr talked to her own classes as well as other teachers’ math classes. Anandkumar talked to students while she served as a sub in other classrooms, while Keller utilized her school’s Elective Fair as a recruiting ground. If teachers were not able to talk with students during school hours or at school-sponsored events as Lamarr, Anandkumar, and Keller were able to do, they might have few opportunities to talk with groups of female students.

Lovelace described a strategy another teacher used. He talked to female sports teams for five or ten minutes at the start of their practice to recruit students for his computer class.
Lovelace explained that the teacher found a great deal of success with this approach since the athletes already knew one another. He found the female athletes were more likely to take the computer science course if they had friends in the class. A survey respondent from Kentucky described something similar, but instead of sports teams, he spoke about social groups. He described the strategy as a snowball effect.

I don't like the idea of recruiting females to meet a quota, however, I do realize that some females who show interest may be intimidated by a predominantly male classroom. By recruiting those girls who already show an interest...these girls are already comfortable in these surroundings, so they have more of a tendency to see it through...Once I got a few girls to show interest and enroll, other girls, who may be a bit intimidated, are more likely to “join the club.” (survey response, November 29, 2018)

As he described, once he was successful in convincing a few female students to try computer science, others quickly followed.

In a related way, Thompson told a story about two recent female students in his AP Computer Science A class. They wrote a flattering piece for the student newspaper about the course. After the story was published, Thompson explained, “[I] had a line of people the next day in my office asking about the course and how they could get involved in it” (interview, December 19, 2018). Many were friends of the two students who wrote the article or from other social groups. Thompson had his highest female enrollment that school year. Even after the buzz from that article died down, he had increased numbers of females taking AP Computer Science A. Thompson, who taught at a smaller school with 400 students, reported having 48 females in his AP class (12% of the school population), which is a significantly higher enrollment than many AP Computer Science A courses across the country.

Anandkumar had a recruitment story similar to Thompson’s. One of her students was the student body president and served in other leadership roles at the school. This student convinced
nine female students to take AP Computer Science A. Anandkumar said, “This girl was a leader, and she convinced her friends. It’s a group of girls who like to do things with groups, and they don’t want to be the lone ones out there” (interview, December 18, 2018).

Anandkumar, Thompson, and Lovelace all found ways to recruit groups of female students. Having a partner to help with recruiting efforts appeared to be a common thread in these teachers’ cases. In Anandkumar and Thompson’s cases, their current students were their partners for recruiting more female students. Lovelace’s colleague who talked to female sports teams had coaches as partners who were willing to give him time for his recruiting pitch. A survey respondent from Arizona found help in her recruitment efforts from two different club sponsors.

I have assistance through recruitment from our Math Society club sponsor. He actively encourages all of his female students to enroll in AP Computer Science A and that has been a great tool for improvement…Many females will be in the Future Business Leaders Association [FBLA] from other classes, but will be encouraged to take computer science to learn more for those events and then more are choosing to continue into AP CSA. (survey response, October 17, 2018)

This teacher found two willing partners in her recruiting efforts. Even though she did not run the Math Society or FBLA clubs herself, the sponsors of those clubs were more than willing to talk to talented students about opportunities in computer science. For teachers without willing partners in the recruiting process, relying on opportunities during school hours, such as subbing, talking to current students, or attending certain school events may be the only avenue they have to find potential female students for AP Computer Science A or other computer science classes.
Recruiting from Younger Grades

A total of six comments came from the survey and interviews to support this final subtheme. The teachers in this study reported that recruiting female students before they reached high school was important. For instance, Lovelace ran a high school program with a fellow engineering teacher called Fem in STEM. In 2018, the club completed their first outreach program with a Saturday workshop that taught female students engineering and programming. Over 100 females from second through eighth grade attended. Lovelace went into detail about the different rotations offered as part of the outreach program.

We did a little rotation thing. I had a bunch of Micro:bit sets so I did a little coding thing where I had them code a little and download it to the Micro:bits, and then, they can play Tic-Tac-Toe against somebody else. Then, the engineering people had them do some kind of a building challenge, and then we also hooked in our astronomy teacher, and she did a little astronomy thing with them so that was really, really successful. We're hoping to kind of show the middle school girls that there's all these options and opportunities for them when they get to high school. (interview, January 4, 2019)

It was Lovelace’s hope that the success of the Saturday outreach workshop would eventually translate to more females in future computer classes.

Wilson had a similar program in which her students went to elementary and middle schools for an after-school event focused on STEM for females. While the event was not as computer-centric as the event run by Lovelace, Wilson believed it helped encourage female students to pursue STEM.

[The teacher at the outreach program] had [students] doing different science activities. Last year they made slime, and they made little towers that had to hold a certain amount of weight. Kind of basic science-y kind of products that you can do in 20 minutes and just having older girls to look up to [got the students to] say “I like this, and I don't care if other people told me I'm not supposed to like it, but I'm going to do this.” (interview, December 13, 2018)
In addition, Wilson’s school district integrated computer science lessons that began in kindergarten. By the time those students reached high school, they had been exposed to computer science for at least nine years. Wilson’s district believed that integrating computer science skills early would help increase gender and racial diversity by giving students confidence in computer science before they began to form stereotypes about the field. One survey respondent also found that adding computer science curriculum at younger grade levels helped her program.

I don't know if you'd call it recruitment, exactly, but we've made programming part of the required 7th grade curriculum - so all students are forced to try it. This has just been implemented in the last few years, and the first set of students that were required to program in 7th are reaching high school now. We are sure to encourage all students that have a knack for programming to continue on with it - and we've identified many female students - so I'm looking forward to these groups of kids being old enough to take APCS. (survey response, October 25, 2018)

While it had only been a few years since implementing the seventh grade programming, she was already seeing dividends in her introductory computer science courses. She posited that many of those students would continue on to take AP Computer Science A, including many females.

To create interest in much younger grades, von Neumann’s high school students ran a three-month after-school program at the elementary level. He explained,

They actually ran a three-month program using Scratch, the drag-and-drop interface. They went to fourth through sixth grade classrooms [for]...like three months, once a week, [to give] after-school workshops. We have a good group of girls here doing things to encourage other girls to join computer science, and they're doing outreach themselves. (interview, January 11, 2019)

von Neumann hoped to continue this program in the future because he believed it generated females’ interest in computer classes. He hoped to find more students in the future to run the program because he believed their participation and enthusiasm contributed to the program’s success.
Overall, the computer science teachers in this study reported using a variety of recruitment practices in an attempt to increase the diversity of their computer science classrooms (i.e., during school, in groups, and in younger grade levels). However, once female students joined a computer science class, the curriculum and instruction the teacher used had the potential to influence female student retention.

**Curricular Practices**

Twenty-two of the 106 teachers surveyed believed the third theme, curricular practices, played a role in recruiting and retaining female students in computer science. The NGSS specify the curriculum of a course plays a key role in increasing representation of underrepresented groups in STEM (NGSS Lead States, 2013). The most common curricular practices teachers mentioned in the interviews included creative projects, real-world projects, and female-only courses.

**Creative Projects**

Anandkumar, Holberton, Knuth, Thompson, and von Neumann all said that creative and engaging projects drew more female students into computer science. An additional six survey participants indicated creative projects enhanced interest. Taken together, a total of 11 interviewees and survey respondents contributed to this subtheme.

Two interviewees mentioned graphical programs as a way to facilitate creativity in delivering the curriculum. For example, both Anandkumar and Knuth made use of open-ended creative projects; however, the latter used them almost exclusively to deliver his computer science curriculum. Knuth explained his approach:
I’ll say make three classes, there needs to be at least two that have a relationship, one is-a relationship, but then you can build around anything you want to have. Boys tend to build videogames, girls build games as well, or just software that they can use in school. (interview, December 17, 2018)

This open-ended approach allowed the students to be creative and make their own choices using graphical programs. Knuth also believed giving the students ownership resulted in more engagement. However, neither Anandkumar nor Knuth mentioned if or how using open-ended creative projects influenced female engagement, although a few survey respondents extended the reason for using creative projects, especially when competing with other electives that appealed to females. One survey respondent detailed this point:

At our very small school, the females tend to take the arts classes as their optional courses outside of the required curriculum. If I can offer a curriculum that allows the students to use computer science as a creative outlet, it seems likely to appeal more to the students. If they can get a foundation of computer science and see the creative potential of it, there is a greater chance of more female students taking up the APCS A course, and studying computer science beyond high school. (survey response, October 24, 2018)

Another survey respondent also found this to be true. She, too, reported that many female students chose creative electives such as art and music. To compete for them to enroll in her computer class, she had to adjust her curriculum and instruction to incorporate more creative projects.

**Real-World/Real-Life Projects**

Six survey respondents believed real-world projects helped recruit and retain female students in computer science. Additionally, four out of the 12 interviewed teachers (Holberton, Hopper, Keller, and Wilson) agreed that real-world projects promoted interest among their female students in AP Computer Science A. For example, Hopper encouraged her students to participate in the Congressional App Challenge. The competition allows middle- and high-school
students to create apps to solve real-world problems. Hopper liked offering this opportunity to her computer science students because of its real-world emphasis on improving society. Other teachers believed creating programs for social good helped female students relate to computer science as a class and occupational field better. Holberton shared, “I’ve really found that some of the female students in my class just linked on to the idea of programming for the purpose of social good as did some of the boys” (interview, December 26, 2018). Holberton had previously focused on game design in her AP Computer Science A course, but she found that it only appealed to students who were interested in videogames, most of whom were boys.

In contrast, Wilson’s school promoted a unique approach to the school’s introductory computer science course. Because every student was required to take that course and knowing that student interest varied, the curriculum team developed three different sections of the introductory course. One section integrated art and music into the computer science content. Another addressed the humanities. The remaining section incorporated math and science. Wilson said because the classes targeted student interest, many ended up using the programs they created in computer science in other courses. While this curricular approach was not designed to specifically cater to female students, research shows that female students are more drawn to computer science when it connects to the real-world and their individual interests (Baker, 2013; Scantlebury & Baker, 2007). Wilson believed this curriculum is one reason she tends to have a good number of female students in her AP Computer Science A course.

A final example came from a survey respondent teaching at a college-preparatory school in Buffalo, New York. He described his rationale for delivering the computer science curriculum using real-life applications and its influence on females.
Projects that have a real-life impact or can be easily seen to be used in real life can help recruit and retain female students. For example, learning about 2D arrays - it's not a topic - it's a project. How do programmers make games like Minesweeper? Or some other relevant real-life scenario…Students are very exposed to elements of computer science on almost a daily basis in itself. Active recruitment can be replaced by word-of-mouth by students themselves. (survey response, September 28, 2018)

This teacher saw the connections between computer science and the real world and believed it was important to show that connection to his students. While his primary goal for developing real-world projects was not recruiting and retaining female students, he found that the projects helped in that regard. Instead of focusing his efforts on recruiting a diverse body of students, he integrated engaging and real-world projects. In turn, students talked about the class with other students, including the practicality of what they were learning. Simple word-of-mouth increased the number of female students taking computer science.

Female-Only Courses

Although researchers have reported that female-only introductory computer science courses may increase participation in more advanced classes (Accenture, 2016; Hoffman & Oreopoulos, 2009), Lovelace was the only survey or interview respondent to mention offering a gender-segregated course at her school. While Lovelace did not have a female-only computer science course at her school, they recently started a female-only version of her introductory engineering course. The curriculum for the general engineering course and female-only section was the same. The school’s purpose for creating two sections was to help female students feel more comfortable in a gender-segregated course and to encourage them to enroll in more advanced courses. Lovelace said the new engineering course almost immediately filled up the first year it was introduced.
Our school administrators are very open to try new things as long as it goes. So they said, we have the curriculum. We’re just going to market to girls only. So they started talking it up...They said “Put it out there and we'll see if it goes. If it fills up, that’s great. We’ll run it. And if it doesn't, then maybe we'll try it again next year.” It's filled up, and there's 28 females in there so it was a success right off the bat. (interview, January 4, 2019)

While the engineering program is still new and there are not enough data at this point to determine how well it works to encourage female students to take and persist in STEM, it is definitely an area for future research. Interestingly, there was no mention of female-only computer science classes by the teachers in this study.

**Pedagogical Practices**

The fourth theme, pedagogical practices, emerged from 20 narrative comments taken from the surveys and interviews. Teachers, according to the NGSS, and the pedagogical practices they employ play a key role in making a classroom friendly for underrepresented groups in STEM (NGSS Lead States, 2013). During the 2018-2019 school year, 91% of the surveyed teachers who had higher than average female student enrollment in their AP computer science classes reported pedagogical practices helped to enroll and retain female students. Pair programming was the most common pedagogical practice the teachers mentioned. Pair programming entails two programmers working together to write computer code. One programmer works as the driver and sits at the computer writing the code, while the other programmer is the navigator and watches the code as it is written to give feedback or advice. The programmers switch roles frequently throughout the day (Williams, 2001).

Five of the 12 interviewed teachers specifically mentioned pair programming as a pedagogical practice they utilized in their classroom (i.e., Anandkumar, Borg, Hopper, Lovelace,
and Thompson). They believed using that practice in their computer sciences classes influenced the gender makeup, including increased numbers of female students. For example, Hopper stated, “I think the female students really like bouncing ideas off each other and talking to each other about what they’re doing” (interview, December 18, 2018). Anandkumar similarly shared, “The female camaraderie and pair programming helped the most with retention” (interview, December 18, 2018). Both Hopper and Anandkumar believed the camaraderie of pair programming attracted female students. While research by Tsan et al. (2016) showed that pair programming using female-only groups is the least effective means of pair programming for student understanding, Hopper and Anandkumar believed it was essential for female student continuation in computer science.

Thompson went into detail as to how he used pair programming in the classroom:

If there's a daily activity in the assignment they want them to work on and it's going to take ten or fifteen minutes, I’ll assign [students] a random partner or two so they're very comfortable with working with different partners and adjusting. I do a little bit of training at the beginning of the year on basic pair programming ideas…and I think that works pretty well. They seem very comfortable with moving to work with another person and there's a structure in place, “Okay, you're going to be this person’s computer. Okay, now you're going to be switching.” They seem to be pretty adept at that. (interview, December 19, 2018)

Thompson believed in pair programming so much that he purposely taught the process to his students at the start of a new term. He also declared that it made all students more comfortable working together and helped build their base of programming knowledge.

According to some of the teachers, this social interaction, as opposed to students working on their projects independently, appeared to not only attract but also retain more females in computer science classes. Pair programming broke down the stigma of being a lone programmer
sitting in a cubicle. Having a mentor – be it a teacher, an industry professional, or another student – can be another way of breaking down stereotypes typically associated with computer science.

**Mentoring Practices**

Seventeen survey and interview responses constituted the fifth and final theme: mentoring practices, which is a practice the NGSS identify is key to promoting gender and racial diversity in STEM (NGSS Lead States, 2013). The computer science teachers talked about using role models to recruit and retain female students and the need to create a sense of community in the classroom.

**Role Models**

A total of 12 survey and interview respondents mentioned using role models to recruit and retain female students in their computer science programs. Anandkumar, Borg, Holberton, Lamarr, Lovelace, and Wilson all talked about bringing in female industry professionals or using older students to serve as unofficial mentors to female students in their classes. For example, Lovelace talked about her Fem in STEM program in that the high school females raved about mentoring and teaching younger students. Some female college students started a Girls Who Code club at Hopper’s school, and she said those college students served as mentors for her female students. Knuth has his older female students teach his freshmen and sophomores skills such as web design or programming to get the younger students excited about continuing with computer science. Borg and Lamarr both used female teaching assistants in their classrooms to help younger students and to serve as role models. Finally, Anandkumar had former female students in college come back to talk with her students. A survey respondent from a public high
school in southern California noted that mentors can be a powerful tool for recruiting and retaining female students: “I believe that both seeing other people that resemble you and BEING the person that others recognize has a powerful effect on the decision to take a class” (survey response, September 27, 2018). This teacher’s comment best captured the overall feeling shared by the other computer science teachers: Seeing female computer scientists/peers being mentored by other females and mentors seeing themselves as influencing others to pursue computer science opportunities can have a powerful effect on recruitment and retention.

Teachers in the survey talked about the difficulty of finding a suitable female mentor to talk to their classes. One teacher from Alabama mentioned time as a limiting factor. “It has been very difficult to find females either in college or already in a STEM field who have time to work with our females or talk to the classes” (survey response, October 1, 2018). Other teachers expressed similar sentiments: it was not only difficult to find good female role models in computer science, but it was also difficult to find female role models who had the time to speak to computer science students.

**Classroom Community**

Three survey respondents and two interview participants specifically mentioned their classroom community as informal mentoring. Turing and Knuth, for instance, spoke about their classroom community and the support they provided. While neither of them said they created their classroom community to specifically encourage more females to take computer science classes, Turing described the situation best when he said, “I think female students are aware of the fact that my classes are a safe place to be” (interview, December 17, 2018). Turing’s response ties to the recruitment practices section and how students can recruit other students
through word-of-mouth. One survey respondent succinctly made this point: “Talk is cheap. They need to hear from their friends that the class is interesting and they are welcomed” (survey response, October 25, 2018). Building a strong classroom community and having a teacher who serves as an informal mentor by creating a supportive safe environment can help female students feel welcomed in a computer science class.

Additionally, five of the eight teachers interviewed for this study thought their role as a female teacher in the computer science classroom helped attract and retain female students. Borg shared evidence that her school’s introductory computer science class taught by a male teacher had lower female enrollments than her own AP computer science class.

I think that at least part of my higher than average female enrollment is the fact that I'm a female. In the beginning Python class, which was taught by a guy, the numbers stayed low. His percentages are much lower than mine. (interview, December 27, 2018)

In support of what Borg shared, Holberton was more succinct: “I think the fact that I'm a female teacher maybe makes some girls feel a little bit more comfortable in the class than if I were a male” (interview, December 26, 2018).

However, during Wilson’s interview, she remembered reading research that indicated the gender of the teacher did not make a difference for female students taking computer science.

My gut instinct is to say that because I am a young female and I am a computer science person, girls can kind of see me and they can be like me some day. But the research shows the gender of the mentor doesn't really matter as much as the mentor’s openness. (interview, December 13, 2018)

Wilson was right. Research exists that shows a mentor’s openness can make a difference in female retention in STEM classes (Margolis & Fisher, 2002). However, contradicting Wilson’s statement, recent research shows female teachers can have a positive and significant effect on
female students persisting with a STEM field (Sterns, Bottía, Davalos, Mickelson, Moller, & Valentino, 2016).

Summary of Outcomes from Research Questions 1 and 2

Teachers who had a higher than average enrollment of female students in AP Computer Science A used all five categories of practices: extracurricular, recruitment, curricular, pedagogical, and mentoring. For extracurricular practices, the teachers mainly implemented national programs such as Girls Who Code and robotics clubs such as FIRST Robotics. Some of those programs were for only females and offered as extracurricular activities year-round to increase female enrollment. The teachers also used three different recruiting strategies to increase female enrollment. They detailed how they recruited during the school day or at school events, from social groups, or by working with younger students. A common curricular practice utilized by the teachers involved building computer science courses around creative and real-world projects. However, none of study participants mentioned offering a female-only computer science course as part of their curricular initiatives. The only pedagogical practice teachers cited consistently was pair programming. While teachers did not use pair programming every day in their computer science classrooms, they believed the camaraderie of pair programming was a factor in increasing their female student enrollment. Finally, the teachers reported using role models to help mentor and encourage female students. Specifically, they found seeing female computer scientists/peers, being mentored by other females, and mentors seeing themselves as influencing others to pursue computer science opportunities had a powerful effect on recruitment and retention.
Research Question 3

The final research question to be answered was “Which practices do computer science teachers perceive as most and least influential in increasing female student enrollment in AP Computer Science A courses and why?” Table 4 shows the number and percentage of practices the survey respondents chose as their most or least influential practices. Data from the teachers who were interviewed are reported in separate columns to foster comparisons between their views and those of the survey respondents.

Table 4

Research Question 3: Most and Least Influential Practices

<table>
<thead>
<tr>
<th>Theme</th>
<th>Most Influential Practice (Survey Respondents)</th>
<th>Most Influential Practice (Interview Subjects)</th>
<th>Least Influential Practice (Survey Respondents)</th>
<th>Least Influential Practice (Interview Subjects)</th>
</tr>
</thead>
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<tr>
<td>Recruitment Practices</td>
<td>48/106 (46%)</td>
<td>4/12 (33%)</td>
<td>7/106 (6%)</td>
<td>0/12 (0%)</td>
</tr>
<tr>
<td>Pedagogical Practices</td>
<td>19/106 (18%)</td>
<td>5/12 (42%)</td>
<td>21/106 (20%)</td>
<td>2/12 (17%)</td>
</tr>
<tr>
<td>Mentoring Practices</td>
<td>16/106 (15%)</td>
<td>1/12 (8%)</td>
<td>9/106 (9%)</td>
<td>2/12 (17%)</td>
</tr>
<tr>
<td>Curricular Practices</td>
<td>11/106 (11%)</td>
<td>2/12 (17%)</td>
<td>34/106 (33%)</td>
<td>6/12 (50%)</td>
</tr>
<tr>
<td>Extracurricular Practices</td>
<td>10/106 (10%)</td>
<td>0/12 (0%)</td>
<td>33/106 (32%)</td>
<td>2/12 (17%)</td>
</tr>
</tbody>
</table>

Most Influential Practices: Recruitment and Pedagogical

Of the surveyed teachers, 46% (48 out of 106) reported recruitment practices increased the enrollment of female students in their AP Computer Science A course the most. However, the interviewed teachers identified pedagogical practices as the most influential (42% of the
responses). In stark contrast, only 18% of the surveyed teachers (19 out of 106) rated pedagogical practices as their most influential practice.

The teachers who indicated that recruitment was the most influential practice agreed that female students have misperceptions that computer science is about “hardware or gaming” (although this misperception could apply to male students as well). One survey respondent succinctly shared this point: “Girls don’t know the course or it’s [sic] contents” (survey response, October 9, 2018). Thus, outreach was essential to recruit more female students to address misconceptions about computer science.

Other teachers mentioned the difficulty of AP Computer Science A as a recruitment barrier for entry. As one teacher explained, “Students are afraid of taking something that will challenge them regardless of gender” (survey response, October 25, 2018). Therefore, encouraging female students to enroll may be what is needed even though perceptions of difficulty exist. In addressing this point, five of the 12 interviewed teachers mentioned the importance of personally connecting with students. While some teachers sent recruitment letters to students or contacted parents or students at home, all five found that talking with students one-on-one was an effective recruiting tool. A survey respondent noted, “My recruitment letter points out that girls often achieve the top scores” (survey response, October 25, 2018). This teacher took it a step further by addressing the confidence issue in his recruiting letter. Lovelace mentioned in her interview that she recruited female students from her math classes as well as talented females from the math team she sponsored. By doing so, Lovelace used the recruitment strategy of making personal connections and building confidence with current female students.

One teacher from Alabama described the approach in this way: “Any time you talk one-on-one
with a student either because they need additional help or because they have strong potential in a subject, it makes them more willing to put forth the extra effort or challenges them to try something new” (survey response, October 1, 2018). So building personal relationships along with encouraging female students to enroll in a challenging course may be key to recruiting them into the computer science classroom.

The teachers found that parents and counselors tended to have a large influence on the elective courses students take, so the teachers often directed recruiting efforts at these two groups. One teacher mentioned she needs to “yell at counselors” (survey response, October 8, 2018), but most of the teachers said that talking with the counselors about the benefits of computer science for female students was a more diplomatic approach. A teacher on the East Coast noted, “I talk to other math teachers and guidance counselors to encourage them to encourage girls in particular to take AP Computer Science” (survey response, September 28, 2018). Knuth had a good enough relationship with his school’s guidance counselor so he convinced the counselor to add female students to his class wait list before male students.

Counselors are important stakeholders when recruiting female students for computer science. Parents are another stakeholder teachers may need to contact when trying to recruit female students. Hopper talked about emailing parents and keeping in touch with them about computer science.

I might have to [email parents more] this year because I don't think I'm going to have as many students as I do this year. Sending a note home or emailing parents or catching them on parents night and just kind of putting the buzz in their ear [can help with recruiting]. (interview, December 18, 2018)

Hopper believed that parents are a key part of recruiting since they have a lot of sway over what courses students take. In some schools, the parents might already have an inclination toward
computer science. von Neumann taught at a school near the campus of a large technology company, and many of his parents saw the importance of computer science. “I think our community wants computer science…It’s not the rich entity for the special kids it’s really something that’s part of the school in general” (interview, January 11, 2019). The parents in his community are engineers or computer scientists themselves, and their influence on their children has led many students to take computer science courses as electives.

A key difference that emerged from this study was the interviewed teachers put pedagogical practices ahead of recruitment. Forty-two percent of interviewed teachers rated pedagogical practices as their most influential practice, while only 18% of survey respondents did the same. Holberton specifically mentioned this difference when she said, “While recruiting girls is important, I think pedagogical practices play a larger part in retention” (interview, December 26, 2018). Her point was that if teachers recruit female students to take a computer science class and then use poor pedagogical practices that result in students leaving the computer science track, then the recruiting was for naught. To prevent this from happening, five of the interviewed teachers (Anandkumar, Borg, Hopper, Lovelace, and Thompson) rated pair programming as an important pedagogical practice to increase and retain female enrollments. One of the benefits of using this pedagogical tool is it favors social interaction. As shared by Hopper, “I think the female students really like bouncing ideas off each other and talking to each other about what they’re doing” (interview, December 18, 2018). Hopper believed the social aspect of pair programming specifically appealed to female students.

In contrast, two interviewed teachers (Thompson and Wilson) found pedagogical practices were the least influential practice for increasing female enrollment in AP Computer
Science A. Wilson said, “I think that students aren’t thinking about how a class is taught when they pick a course. I think they are listening to other students’ experiences and responding to the teacher” (interview, December 13, 2018). Wilson focused on the recruiting aspect of this research question because in her opinion, a teacher cannot retain female students in computer science if the teacher does not successfully recruit them. However when selecting pedagogical practices as the most influential practice, Borg said, “Students choose courses by reputation. As the girls succeed without trauma, they encourage other girls” (interview, December 27, 2018). Pedagogical practices can serve as another form of recruiting. If students enjoy a teacher and a class, they will talk to other students about the class. If pedagogy is used appropriately to create an enjoyable learning environment, students will speak highly of the course and more students are likely to join.

**Least Influential Practice: Curricular**

Although the NGSS identified curriculum as an important aspect of increasing gender diversity in STEM (NGSS Lead States, 2013), 33% of the surveyed teachers (34 out of 106) and half of the interviewed teachers (six out of 12) rated curricular practices as the least influential practice to recruit and retain female students in AP Computer Science A. As one survey respondent from Wyoming explained, “How will girls know you changed your curriculum if they aren't in there in the first place? It's all about the relationships you have with students” (survey response, November 29, 2018). Teachers attract students to a class by the teacher’s expertise and the opinion of students who have taken the class. As Lamarr stated, “Most in the class, boys and girls are both able to handle the curriculum. It is getting them interested that is the hard part. Once I have them there, I can teach them the rest” (interview, December 12, 2018).
The survey also brought to light that female students need support once they enrolled in a computer science class. von Neumann posited, “Each of the practices matters but girls will generally do whatever curriculum is presented as long as there’s a culture of support and excellence” (interview, January 11, 2019). While the curriculum was important to von Neumann, it did not matter unless the female students felt supported and challenged by their teacher. A survey respondent who identified mentoring as the most influential practice stated that “females need to know that they are important in the CS class and that they will get the same kind or better support than the males” (survey response, October 25, 2018). The same survey respondent said, “Talk is cheap. Female students need to hear from their friends that the class is interesting and they are welcomed” (survey response, October 25, 2018). This survey respondent agreed with von Neumann and Lamarr, who argued that students found feeling welcome and supported in the classroom was more important than the curriculum.

While the curriculum for AP Computer Science A is dictated by the College Board, it is up to teachers to tailor that curriculum to fit their particular situation. Five teachers (four from the survey and one interview respondent) did not feel modifying the curriculum to appeal to female students was a good approach. For example, a teacher from Texas noted, “I don’t think most of the girls care about curriculum being tailored to them. They prefer to show they are capable and interested in the subject matter just as it is” (survey response, September 27, 2018). A teacher from Alabama similarly added, “The work won’t be modified in any way to appeal to females after they get a degree so why would I modify the curriculum to appeal to females? It should be as realistic as possible” (survey response, September 27, 2018). Finally, a teacher from a college preparatory school provided a rationale for choosing curriculum as least influential: “I
chose curricular only because it was the least incorrect choice. Personally, changing curriculum to attract females is a horrible idea” (survey response, October 8, 2018). Anandkumar, a bit more gentle in his wording, explained: “I’m not really keen on making curriculum more female friendly. I want it to remain gender neutral. For many projects, students have the option of making the project specific to their interest” (interview, December 18, 2018).

Research Question 3 Overview

The survey respondents identified recruitment practices as the most influential factor for increasing female enrollment in computer science courses. Whereas the interview subjects saw pedagogical practices as having the most influence. They specifically mentioned the benefits of using paired programming. Both the survey respondents and interviewed teachers agreed that curricular practices were the least influential factor in increasing student enrollment.

Chapter Summary

The first section of this chapter included a description of the AP Computer Science teachers who completed the survey, followed by detailed descriptions of the 12 participants who were interviewed. The remainder of the chapter focused on the themes and outcomes to answer Research Questions 1, 2, and 3. In the final chapter, I discuss the findings in light of past research and the theoretical framework chosen for this study. Then I offer recommendations for the field as well as for future researchers.
CHAPTER 5
DISCUSSION

The purpose of this mixed methods study was to investigate practices used by computer science teachers who have a higher than average enrollment of female students in their AP Computer Science A classes. This chapter begins with a discussion of the three major themes with references to how they relate to the theoretical framework and existing research. Then recommendations for computer science educators and future research are detailed. Finally, the chapter concludes with a discussion of the limitations of the study.

Major Insights that Emerged about Recruitment and Retention Practices

Three major insights emerged from the research. I begin with discussion of recruitment and how it can be implemented to increase enrollment and retention of female students in computer science. Parents and counselors emerged as key gatekeepers to teachers’ recruiting efforts. It is important that teachers talk to students directly, if possible, and educate key stakeholders about computer science. I also identify pedagogical practices that can be used in the classroom, as that was the most influential practice according to the teachers who have had success recruiting and retaining female students. Pair programming specifically emerged as a key practice these teachers utilized that led to increased female student retention. Finally, I present curriculum, which was the least influential practice according to the survey respondents. I
describe some reasons why teachers did not rate curriculum as highly influential and how curriculum can be used to increase female recruitment and retention in computer science.

**Recruitment Practices**

The Next Generation Science Standards (NGSS) do not mention recruitment as a major practice for attracting female students in science (NGSS Lead States, 2013), so the fact that AP Computer Science teachers believe it is the most influential practice for recruiting and retaining female students is revealing and adds to the existing research. A key challenge for computer science teachers was the lack of knowledge most students have about computer science, so they felt that recruitment is a key element for filling the gaps all students have about the study of computer science.

Recruitment practices appeared to be the easiest of the five practices to implement for these teachers; however, research shows that changing pedagogical practices (Park & Ertmer, 2008) or curriculum (Marzano, 2003) can involve hours of research and other work, which could be off-putting to teachers and cause them to seek easier practices to implement. Furthermore, confirming Sanders (1994) research, adding an extracurricular club can similarly involve a lot of work and potentially levels of bureaucracy to navigate. Similarly, Sanders noted that setting up a specific mentoring program can be difficult, especially if you want to find high-quality female mentors in the computer science field. While extracurricular clubs and mentoring are two of the three practices the NGSS identified can lead to better female engagement in science (NGSS Lead States, 2013), the participants in the current study refute that research to a degree by saying that
female students cannot be engaged in computer science if they do not take computer science classes.

*Unlocking the Clubhouse* by Margolis and Fischer (2002) focused on recruitment more than any other practice. Even if their focus was mostly on college instructors, they spent an entire chapter detailing ways teachers can recruit more female students for their computer science classroom. Margolis and Fisher noted that educating counselors and parents was an important component of recruiting because computer science is just as nebulous a subject to adults as it is to students. Many parents and counselors do not understand the difference between computer science and computer applications, which can lead to a misunderstanding about what constitutes a computer science course. Counselors and parents were both discussed in the survey results as paths to recruiting female students. Confirming the research of Margolis and Fischer (2002), focusing recruiting on those gatekeepers can increase the effect of recruitment efforts of female students as shown in Figure 1. The teachers of elective courses knew they needed to do everything in their power to keep or increase enrollment in their courses, so they also needed to communicate with two major gatekeepers (parents and counselors) to students taking computer science courses.
The participants in the current study also talked extensively about their interactions with female students as a recruitment effort, a confirming research by Sanders (1994) as well as Margolis and Fischer (2002). One teacher discussed going to female sports teams and talking to students at their sports practices about taking computer science courses. The power of recruiting social groups is something Margolis and Fischer (2002) identified in their chapter on recruitment and it is an untapped recruiting ground for many computer science teachers (Sanders, 1994).

As noted by Margolis and Fisher (2002), education about computer science and talking to female students directly are two of the most important aspects of recruiting (see Figure 2). Confirming research by both Sanders (1994) and Margolis and Fisher (2002), teachers need to get in front of students and talk to them about the benefits of computer science. Recruitment letters can reinforce the educational benefits of taking computer science courses, but a personal connection with those students is ultimately needed to convince students that computer science is a good choice for them.
While most of the research on recruiting focuses on getting in front of students (Alvarado & Dodds, 2010; Margolis & Fisher, 2002; Sanders, 1994), including a survey for students could help gather information about their interests or club participation. This can help teachers determine what sports or clubs to target with recruiting efforts, and adds to that previous research.

Although older research, Sanders’ (1994) findings served as a basis for the five categories of practices (recruitment, pedagogical, mentoring, curricular, extracurricular) I used for the first research question. Sanders found that all-female programming teams helped with female confidence in computer science, paralleling more recent research by Margolis and Fischer (2002) as well as Alvarado and Dodds (2010). Alvarado and Dodds recommended female-only events to build female confidence in computer science, while Margolis and Fischer found that female-only events or clubs could help build female confidence in computer science. Thirty-two teachers in

Figure 2: The pillars of recruiting female students for computer science.
my survey and interviews mentioned all-female extracurricular programs (e.g., Girls Who Code, Technovation, and Black Girls Code) at their schools to confirm that research by Margolis and Fischer (2002) and Alvarado and Dodds (2010). They also noted that the programs provide a readily-available avenue for face-to-face recruitment of female students if the teachers are sponsors of the clubs or have a close connection to the sponsor. While extracurricular clubs were not the most important practice for recruiting and retaining female students in computer science, the participants acknowledged that extracurricular clubs can form a piece of an overall recruitment effort for teachers so they should not be entirely discounted. Confirming research by Margolis and Fisher (2002) and Alvarado and Dodds (2010), female-only clubs can be another avenue to spark female interest in computer science. If females have a good experience in a club such as Girls Who Code, they may be more likely to take computer science classes.

Pedagogical Practices

The Next Generation Science Standards (NGSS) emphasize pedagogy. Freire (1968) also noted the importance of pedagogy and contended that the relationship between students and teachers reinforces the inequities of society. Freire noted that teachers could better serve students by leading them through their own learning process. Confirming research by Sanders (1994), if teachers have a relationship with their students in a computer science classroom that focuses on male-oriented activities, it can create a hostile environment for female students. This also confirms research by the NGSS (NGSS Lead States, 2013) as the NGSS identified instructional strategies (pedagogy) as one of three key areas in which to engage females in the classroom (the other two are curriculum and after-school clubs). The current research emphasized the
importance of instructional strategies for retaining female students in the computer science classroom, which agrees with research related to the NGSS. This also confirms Margolis and Fisher (2002) who found that teachers who use research-based pedagogical practices and who provide a more enjoyable learning environment for students are probably going to attract more students regardless of gender.

What goes on inside the classroom is important to students, and Sanders (1994) and Goode (2007) recognized that students talk to each other about the classes they take. If a teacher is pedagogically strong and implements researched-based pedagogical practices while fostering a supportive learning environment, it is more likely students of any gender will want to take that teacher’s classes. Beyer (2014) found that strong instructors played a key role in women persisting in computer science, while the instructor did not make a difference for men’s persistence. This appeared to be true based on my research, as pedagogical practices, like pair programming, were more strongly connected to the teacher than any other practice. Since pair programming was the most-mentioned pedagogical practice in this study, it stands to reason that they believed it can be a powerful practice for retaining female students in computer science.

Sanders (1994) noted that pair programming is probably the pedagogical practice teachers can implement with the least amount of time in an attempt to retain more female students. While Tsan et al. (2016) found female-female programming pairs may underperform other pair combinations in computer science, Margolis and Fisher (2002) identified the importance of pair programming for female retention in computer science. Based on the results of this study, it can be a practice to boost female enrollment and increase female student confidence in computer science. This confirms the research by Margolis and Fisher (2002) and
refutes the research by Tsan et al. (2016). By having a programming partner, students always have someone to support them and someone who is also going through the same travails to write a computer program. Williams (2001) stated that having this built-in support system can greatly increase a student’s confidence.

**Curricular Practices**

The survey respondents and interview participants in the current study rated the curriculum as the least effective practice for increasing female student enrollment in computer science. This refutes research by the NGSS (NGSS Lead States, 2013). Teachers rating curriculum last does not mean it is not an effective practice, since the NGSS noted the importance of curriculum (NGSS Lead States, 2013) for female engagement in the science classroom. It does show these teachers did not believe the curriculum had a large effect on their female students. Freire’s (1968) critical pedagogy contended that curriculum can be used, purposefully or inadvertently, to oppress certain populations. This was also seen in Carter’s (2006) and Margolis and Fisher’s (2002) research, which found the use of a computer science curriculum focused on male-oriented activities such as videogames can be an example of teachers inadvertently oppressing female students by focusing on curriculum that has little intrinsic value for them.

While avoiding male-oriented activities in the curriculum is important, Margolis and Fisher (2002) found that the curriculum in a computer science classroom does not need to be tailored specifically for female students, which is a concern some teachers in the current study had. Teachers need to teach specific standards in AP Computer Science A, but the way they
address those standards is left up to them. Tailoring curriculum to female students is an idea many teachers dismissed when responding to my survey. However, a curriculum may inadvertently be focused toward male students, which can be a barrier for female student enjoyment of computer science, as Margolis and Fisher (2002) reported. Sanders (1994) saw a good computer science curriculum should involve real-world projects and show the connections between computer science and other fields, which is confirmed by the AP Computer Science A teachers in this study supported that point. In addition, Margolis and Fischer (2002) identified that keeping a positive classroom climate was important. This point, too, was echoed by teachers in the current study.

Despite teachers rating curricular practices the least effective practice, research says that it is an important aspect of a gender-inclusive classroom (Goode, 2007; Margolis & Fisher, 2002; Sanders, 1994). The curriculum does not have to be specifically geared toward female students, but it also should not be hostile to them by focusing too much on activities, such as videogames, that appeal more to male students. However, with teachers in this study rating it as the least effective practice, it could be that curriculum does not have the same effect previous research found or the teachers from my study could be underestimating its effect. It is also possible that these teachers believed they have no control over the curriculum for AP Computer Science A because it is dictated by the College Board. As stated earlier, while teachers cannot change the standards they teach, they do have broad latitude in how they implement those standards.
Recommendations to the Field of Education

This section provides recommendations for computer science teachers. While this research was focused on practices used by AP Computer Science A teachers, these practices can be applied to computer science teachers at any level. Based on the findings, I have three recommendations in the areas of pedagogy, recruiting, and curriculum.

Computer science teachers should implement pair programming in their classrooms. Sanders (1994) talked about how pair programming can help inspire confidence in female students well before current research on pair programming noted the benefits of the practice (Williams, 2001; Williams et al., 2000). Pair programming was the only pedagogical subcategory I created based on comments from my participants, and 20 survey and interview participants mentioned it. Pedagogical practices can benefit all students (Margolis & Fisher, 2002), but the teachers who have the most success recruiting and retaining female students in computer science believe pedagogy is essential. Furthermore, implementing pair programming is not a difficult practice to implement (Sanders, 1994), especially if a teacher starts at the beginning of a school year or a semester. The teachers I interviewed used pair programming throughout the course of the semester, but as with any pedagogical practice it is important to make sure it is introduced and explained to students thoroughly.

Teachers should also do everything they can to educate important gatekeepers, such as parents and counselors, about computer science and how it differs from traditional courses in computer applications (Margolis & Fisher, 2002; Sanders, 1994). Creating a short document explaining the different computer science courses and who should take them can help. Talking with counselors in person or through email can be helpful as well (Margolis & Fisher, 2002;
Sanders, 1994). Teachers also need to find ways to get in front of students and talk to them about how they can succeed in computer science. Talking to social groups, sports teams, homerooms, or math classes were common ways these teachers talked to students, practices emphasized by Sanders (1994).

Finally, a curriculum specifically tailored to female students may not be necessary, but as the NGSS argues (NGSS Lead States, 2103), it is important female students are at the forefront when curriculum is modified or developed. While the College Board specifies the standards students need to meet in AP Computer Science A, the curriculum teachers use for other computer science classes can have an effect on whether female students move on to AP Computer Science A. Teachers should not develop a curriculum focused on geeky elements, such as science-fiction or violent videogames, that may not appeal to female students (Accenture, 2016; Bock et al., 2013; Margolis & Fisher, 2002). Incorporating real-world applications and showing the connections between computer science and other fields is important for all students but can have a great impact on female appreciation of computer science.

Future Research

Future research should address curriculum focused on creative real-world projects to determine the effects on female enrollment. While the College Board (2020) has a set of standards teachers must ensure students meet in AP Computer Science A, teachers are given broad latitude in implementing those standards as they see fit. The NGSS (2013) indicate curriculum is a major factor for increasing female engagement in science, but the teachers in my study suggested curriculum was the least effective practice for increasing female enrollment in
computer science. Therefore, implementing a curriculum in a computer science classroom that focuses on creative real-world projects or a curriculum that would otherwise appeal to female students could help determine how effective curriculum can be in diversifying a computer science classroom. If teachers implement a curriculum and see how it affects their female enrollment, it could be telling over a period of four or five years and with different teachers if it makes a difference in female enrollment in AP Computer Science A.

Although suppositions and anecdotal evidence suggest that a female-only introductory class can promote female student confidence in STEM fields (Accenture, 2016; Hoffman & Oreopoulos, 2009), no hard research shows that a female-only introductory computer science class can increase female enrollment in computer science. While creating this type of program can be difficult, schools have successfully created female-only engineering classes as in the case of Lovelace’s school, so schools should be able to create female-only computer science classes as well. A school could implement an introductory female-only computer science course and see if it leads to an increase in female persistence in computer science by noting an increase in AP Computer Science female students or female students going on to major in computer science.

Pair programming was a pedagogical practice used by many teachers in this study. Future research looking at the best practices for pair programming would be helpful for teachers looking to implement it in their own classrooms. Additionally, research into best practices for peer supports in computer science other than pair programming could be helpful to build a classroom community.

Future research could build on this current study by examining how teachers at different types of schools employ various approaches to recruiting and retaining female students in AP
Computer Science A. A comparison of large schools versus small schools, public versus private schools, or schools in different areas of the country could assist teachers in fine-tuning what strategies might work for them in their own classrooms. For example, does an AP Computer Science teacher at a small school establish relationships with students much easier than a large school? Do strategies used by AP Computer Science teachers differ between public versus private schools? Future research could also try to find a better way of recruiting participants.

This study had to resort to personally contacting some teachers in Illinois, which could have led to skewed results. Finding a way to utilize the College Board to recruit teachers either through a direct mailing to those teachers or through the College Board’s official forums could lead to more participation without coaxing participants.

Using the current study to look at different underrepresented groups, such as students of color, could help capture their voices. Specifically looking at female students of color could help show how they differ from female students in general.

One final recommendation for future research involves duplication of my methods to determine if they result in the same findings regarding female recruitment and retention in other STEM fields. While states across the country require courses in math and science, engineering is typically an elective. It would be helpful to see if my findings also apply to engineering or if they are specific to computer science. In addition, since my research began a second AP Computer Science course was created by the College Board called AP Computer Science Principles. This course has seen tremendous growth and is meant to be a course with broader appeal than AP Computer Science A. It would be interesting to see if a study similar to mine with AP Computer Science Principles teachers instead of AP Computer Science A teachers would garner similar
results. For researchers who consider using my survey instrument, I would strongly recommend keeping the open-ended questions as they provided nearly as much helpful qualitative data as the interviews. I did have questions about AP exam scores on the survey. However, I would propose those questions be removed.

Limitations

Since teachers in the qualitative portion of the study taught in schools across the country, I used electronic means to conduct the interviews. Participants can be less forthcoming in interviews through electronic means and judging body language becomes difficult (Kazmer & Xie, 2008). I conducted these interviews toward the middle of the school year, so teachers may not have accurately remembered details from the previous school year. If a researcher had the means to conduct more interviews in person, it would be a good way to validate the current research.

Additionally, I set a goal of 325 survey responses to achieve statistical significance for this study. I fell short of that goal with 106 responses. While I originally used several avenues to recruit teachers for this study, I also reached out to teachers I knew in Illinois. This may have skewed the results by selecting more teachers from Illinois and eliminated the chance for a true random sample. There also were not a lot of responses from the southern United States, which also hurt the chance of a true random sample.

Finally, the teachers stated their opinions on successful strategies for recruiting and retaining female students in their classes. Few teachers mentioned curriculum, even though research shows it can be a major factor in recruiting and retaining female students. That finding
could result from teachers not realizing the impact of the curriculum, but my research could not determine that.

Conclusion

I set out to investigate the practices of computer science teachers who have a higher than average enrollment of female students in their AP Computer Science A classes. Those teachers believed their pedagogical practices played the most important role in increasing female student enrollment in computer science. All interviewed teachers used various practices (pedagogical, recruitment, mentoring, curriculum, and extracurricular), but they rated pedagogical as the most effective. Recruitment practices ranked as the most influential for the survey respondents. It is also important that teachers educate stakeholders about computer science and try to connect with students in person. Counselors and parents are influential gatekeepers who may need to be included in the recruiting process to achieve success.

Since these teachers had success with gender diversity in their classrooms, their belief that pedagogical practices rank as the most influential practice lends credence to that belief. Pair programming was the only pedagogical practice consistently mentioned by respondents, but other research-based pedagogical practices such as valuing students’ voices and perspectives can also help increase female enrollment in computer science classrooms.
REFERENCES


Board of Trustees at the University of Illinois. (2016). CS + X degree programs. Retrieved from https://cs.illinois.edu/academics/undergraduate/degree-program-options/cs-x-degree-programs


APPENDIX A

PARTICIPANT CONSENT FORM
I agree to participate in the research project, titled *Examination of Practices Used by AP Computer Science Teachers with Higher than Average Female Enrollment*, being conducted by Derek Miller, a graduate student at Northern Illinois University. I have been informed that the purpose of the study is to determine teaching practices that may be associated with increased female enrollment in secondary computer science classrooms.

I understand that if I agree to participate in this study, I will be asked to participate in a 30-minute interview through a teleconferencing app and confirm the transcription of that interview at a later date.

I am aware that my participation is voluntary and may be withdrawn at any time without penalty or prejudice, and that if I have any additional questions concerning this study, I may contact Elizabeth Wilkins at [email protected]. I understand that if I wish further information regarding my rights as a research subject, I may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

I understand that the intended benefits of this study include better ideas for recruiting female students for AP Computer Science and I will have access to the final paper once it is complete. I have been informed there are no foreseeable risks to my participation in this research. I understand that all information gathered during this experiment will be kept confidential with pseudonyms being used for my name and school in the final paper.

I understand that my consent to participate in this project does not constitute a waiver of any legal rights or redress I might have as a result of my participation, and I acknowledge that I have received a copy of this consent form.

Signature of Subject

Date

__________________________

The signature below indicates I am consenting to be audio/video recorded for an interview.

Signature of Subject

Date

__________________________
APPENDIX B

AP COMPUTER SCIENCE SURVEY
AP Computer Science Survey

This survey will be used to collect data for a project by Derek Miller at Northern Illinois University. The results will be analyzed, and a number of teachers will be selected for follow-up interviews. The survey results will be anonymous from everyone but the researcher, as you may be asked to consent to a follow-up interview. Completion of this survey does not necessarily mean you have to consent to an interview. This survey should last around 20 minutes.

There are no reasonably foreseeable risks to your participation in this survey. Results of this research will be shared with all survey and interview participants so you can hopefully gain new ideas for recruiting and retaining girls in computer science.

If you have any questions about this research, you can contact me at Z1717366@students.niu.edu or Northern Illinois' IRB office at 815-753-8588 or researchcompliance@niu.edu.

* Required

I agree to the terms stated above. *

Mark only one oval.

Yes Skip to question 2
No

AP Computer Science A Course Information

This section asks questions about your AP Computer Science A courses from the current school year and previous school year.

How many total students took AP Computer Science A with you during the 2017-2018 school year? *

How many FEMALE students took AP Computer Science A with you during the 2017-2018 school year? *

How many total students are taking AP Computer Science A with you during the 2018-2019 school year? *

How many FEMALE students are taking AP Computer Science A with you during the 2018-2019 school year? *

How many of your students received a score of 5 on the 2018 AP Computer Science A exam? *
How many of your students received a score of 4 on the 2018 AP Computer Science A exam? *

How many of your students received a score of 3 on the 2018 AP Computer Science A exam? *

How many of your students received a score of 2 on the 2018 AP Computer Science A exam? *

How many of your students received a score of 1 on the 2018 AP Computer Science A exam? *

Classroom Practices

How many of your FEMALE students received a score of 5 on the 2018 AP Computer Science A exam? *

How many of your FEMALE students received a score of 4 on the 2018 AP Computer Science A exam? *

How many of your FEMALE students received a score of 3 on the 2018 AP Computer Science A exam? *

How many of your FEMALE students received a score of 2 on the 2018 AP Computer Science A exam? *

How many FEMALE students received a score of 1 on the 2018 AP Computer Science A exam? *

Which of the following practices do you employ that you believe help retain female students in your computer science classes? *

Check all that apply.

- Recruitment (Do you actively recruit female students for your classes in any way?)
- Pedagogical (Do you use pair-programming, open-ended assignments, or other techniques?)
- Mentoring (Do you use female students or college students as mentors?)
- Curricular (Have you modified your curriculum to appeal more to females?)
- Extracurricular (Have you added an after-school club or event to appeal to females?)

Please explain in detail any of the practices you selected above.

Which of the following practices do you believe is the MOST influential in retaining female students in your computer science classes? *
Mark only one oval.
Recruitment
Pedagogical
Mentoring
Curricular
Extracurricular

Why do you believe your choice above is the MOST influential? *

Which of the following practices do you believe is the LEAST influential in retaining female students in your computer science classes? *
Mark only one oval.
Recruitment
Pedagogical
Mentoring
Curricular
Extracurricular

Why do you believe your choice above is the LEAST influential? *

Demographic Information

What is your gender? *
Mark only one oval.
Female
Male
Prefer Not To Say

Would you be willing to participate in an online interview about your AP Computer Science A course? I will work with your schedule to find a time convenient for you. *
Mark only one oval.
Yes
No

Contact Information

This contact information is necessary if you are chosen for an online interview. If you do not want to give your contact information, please return to the previous section and opt out of the interview.
How many years have you taught AP Computer Science *
Your Name *
Your Current School *
Phone Number
Email Address *
APPENDIX C

EMAIL RESPONSE FROM DR. BARBARA ERICSON
Hi Derek,

It is nice to virtually meet you. Glad to hear that you are working on your dissertation and are researching strategies that AP CS teachers use to attract females to their classes.

The first question was confusing since I assumed you were talking about this year at first. I would add (last year) and (this year) to the questions.

Do you really want this for the whole school rather than per teacher? Some schools have several different teachers teaching AP CS. Also, you don't break out CSA vs CSP. I would.

Each question asks for the total students and doesn't really need to say total.

I would change the "How many total students received a score of 2 on the 2017 AP Computer Science exam? *" to be "How many of your students received a score of 2 on the 2017 AP CSA exam?"

I think the classroom practices part is way too vague. I would explain what you mean by each and have open-ended answer areas as well for the teachers to explain what they mean.

Recruiting of females - do you actively recruit females to your classes and if so how? -

Pedagogy - do you use pair programming or open-ended creative assignments or something else? If yes - what?

Mentoring - do you have former students or college students mentor female students - if yes, who and how?

Curricular - have you modified your curriculum to appeal to females - if so how

Extracurricular - have you added an after school club or other type of event - if so what?
Change - "Would you be willing to participate in an online interview about your AP Computer Science course? *" Tell them how long the interview will be, that you will work with them to schedule it when it is convent for them, and if they will receive anything like a $50 gift card for participating.

Have you talked to Seth Reichelson? If not, you really should. He is a wonderful AP CSA teacher in Florida who has 40% females and hundreds of students.

He used to have only guys in AP CSA until he attended a tapestry workshop and thought about changing his course and recruiting women. He does a great number of things to recruit and to help women in AP CSA.

You might want to talk to Jim Cohoon as well. He runs tapestry workshops to help both high school teachers and community college instructors increase diversity in computer science. See http://delivery.acm.org/10.1145/3160000/3159505/p783-chang.pdf?ip=73.7.150.249&id=3159505&acc=ACTIVE%20SERVICE&key=A79D83B43E50B5B8%2E5E2E401E94B5C98E0%2E4D88A169D0CAE027%2E4D4702B0C3E38B35&__acm__=1527173644_283ba3224801baa3c04baeba4b6ac54a for a paper that he was an author on at SIGCSE

Good Luck,
Barb Ericson
Georgia Tech (Un of Michigan as of Sep 1st 2018)
APPENDIX D

EMAIL RESPONSE FROM DR. JAMES COHOON
I would move all how many female after how many people. I believe it is best to delay your specific interests.

For the question Which of the following practices do you employ, I would add some sort of check all that apply to help the speed readers be aware.

Why not also ask about Black and Hispanics.

Avoid girls in your correspondence and use females instead.

Good luck.
APPENDIX E

INTERVIEW QUESTIONS
1. What was your path to teaching computer science? Did you opt to teach computer science classes or was it more forced upon you?
2. Do you think it is important to get more females to take computer science courses? Why or why not?
3. Have you made a conscious effort to try and recruit and retain females in AP Computer Science?
4. Your AP Computer Science course has more females than a typical AP Computer Science course. What do you attribute that to?
5. Have you used any recruiting strategies to try and recruit more females for AP Computer Science? If so, can you go in to specifics and when and how have you tried to recruit females?
6. Are there any pedagogical practices you’ve employed that you believe help recruit and retain females in AP Computer Science? If so, what are those practices, when do you use them, and how often do you use them?
7. Have you employed mentoring to try to recruit and retain females in AP Computer Science? If so, can you explain the mentoring program?
8. Are there any curricular programs you use to try to recruit and retain females in AP Computer Science? If so, can you explain those programs?
9. Are there any extracurricular programs you use to try to recruit and retain females in AP Computer Science? If so, can you explain those programs?
10. Do you think your success recruiting and retaining females in AP Computer Science can be replicated? If so, what advice would you give other teachers?
APPENDIX F

OPEN AND AXIAL CODES
Open Codes

Math teacher
Personal connection
Recruiting
Girls-only class
Girls-only club
Outreach to younger grades
National program
Pair-programming
Mentoring
Real-world activity
Open-ended projects
Creative projects
Community
Role model
Flipped classroom
Social groups
Teacher gender

Axial Codes

Recruiting
Recruiting
Social groups
Outreach to younger grades
Math teacher

Pedagogical
Pair-programming
Flipped classroom

Mentoring
Mentoring
Personal connection
Community
Role model

Curricular
Real-world activity
Open-ended projects
Creative projects
Girls-only class
Extracurricular
Girls-only club
National program

The Teacher
Personal connection
Community
Math teacher
Teacher gender