SECURING THE CYBER PIPELINE: TOWARD NATIONAL STRATEGIES FOR CYBER WORKFORCE DEVELOPMENT

Tamirat T. Abegaz, University of North Georgia

Bryson R. Payne, University of North Georgia

ABSTRACT

As nations race to build their cyber workforces, a critical shortage of highly skilled labor in cyber is hampering efforts and weakening defensive capabilities as rogue actors progressively grow their offensive capacity. A key element of national policy and strategy will be the development of an adequate pipeline of competent, qualified cyber professionals for the next twenty years and beyond. In one such effort, the United States' National Security Agency, in collaboration with the National Science Foundation, has developed and implemented a program targeted at pipeline development from primary school through college and is sharing information on the program with the international community. This paper presents the NSA-NSF GenCyber project, along with research related to the program's effectiveness, as one approach toward multiplying both cyber and broader related fields' career interest among students in primary and secondary schools as a means to bring forth significantly greater numbers of university graduates in cyber security, computer education, and related fields. Overall, this research suggests that cyber workforce development initiatives like the NSA-NSF GenCyber project can form the basis for building the next generation of cyber professionals and researchers.

Keywords: cooperative/collaborative learning, teaching/learning strategies, pedagogical issues, cybersecurity, gender studies

INTRODUCTION

Computer and Information Systems career interest in the 21st Century

Research indicates that the interest among K-12 students' in science, technology, engineering, and mathematics (STEM) career path is declining (Sadler, Sonnert, Hazari, & Tai, 2012). In fact, the lack of interest in STEM career paths has become a global educational concern. Today, most developing and developed countries realize that STEM is a high-demand career field, important for the sustainable growth of the near-future global economy. Countries have realized that investing in STEM training is extremely valuable for continual innovation, both to improve the livelihood of the world's population and to benefit society as a whole. For instance, in the US, the demand for personnel with cyber expertise in both the public and private sectors for STEM-related professionals exceeds the current supply (Chen, 2013; Sadler et al., 2012). Unfortunately, in almost all STEM-related career professions, women are under-represented (Clark, 2005; Wang, Eccles, & Kenny, 2013). Given the disproportionately low number of girls who are interested in STEM-related fields, it is important for society to encourage and provide the necessary assistance to citizens of all gender and ethnic origins to pursue STEM education. In other words, opening doors early to girls in STEM disciplines and careers, by empowering students with the necessary knowledge and skills in STEM-related fields, is extremely helpful for the sustainability of modern society. Arguably, this could be the best educational investment to enhance the pipeline for future STEM career paths. Meanwhile, the combined efforts by all stakeholders including parents, community leaders, teachers, and governments will help to create a strong and continuing career pathway for both girls and boys in STEM-related fields. Increasing the representation of skilled manpower in STEM-related scientific and technical fields is essential for today's increasingly interconnected global economy. Alternatively, as STEM skills become even more important, strengthening the workforce pipeline will be tremendously helpful for society and impact the potential progress of the world economy at large. Realizing this, various countries have set out long-term and short-term educational objectives to minimize the shortage of skilled human-power in STEM, computer science, cybersecurity, and related fields.

From the US perspective, the National Research Council (NRC), the National Science Foundation (NSF), the National Security Agency (NSA), the Department of Education (DOE), and the Department of Commerce (DOC) are working hand-in hand to prepare students for careers in STEM-related fields (Mau, 2016; Melissa & Bianca, 2015; NRC, 2011). For instance, a report from the NSF indicates that STEM-related workforce demand increased more than 21% and significantly outpaced other career fields (Lehming et al., 2010, Mau, 2013). With regard to K-12 STEM education, three goals were set forth by the US government to overcome current and future shortages of experts in STEM-related fields: "to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy for all students" (NRC, 2011). Particular, it is essential for the government to invest its resources at the family, school, district, state, and national levels to improve STEM education. But further changes in society's STEM culture are needed in order to attract more girls into STEM-related fields to minimize the gender gap. In addition, we must work together as a nation in order to change the attitudes of female students that stereotype STEM fields as careers for males. Recently, various government agencies have collaborated to increase the STEM pipeline for students in entering, completing, and persisting in STEM disciplines. Most recently, due to the efforts of various governmental and non-governmental stakeholders, the gender gap may be turning in the right direction (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Mau, 2016; NRC, 2011). While this has a positive impact, tremendous effort is required to reach to the expected results.

GenCyber training program

The GenCyber program states three main goals: "to increase interest in cybersecurity careers and diversity in the cybersecurity workforce of the Nation, to help all students understand correct and safe online behavior, and to improve teaching methods for delivering cybersecurity content for K-12 curricula" (GenCyber Program Director Guide, 2016). The GenCyber program sponsors free summer cyber camps for K-12 students across the country each summer. Each camp is expected to create opportunities for participants to gain a thorough understanding of cybersecurity principles and practices. Students are expected to leave the camp with a greater awareness of personal, organizational, and national cybersecurity issues, practical experience applying basic cyber hygiene, and the ability to research, analyze, and assess ethical issues in cybersecurity. Generally, the program focuses on delivering ten cybersecurity first principles: abstraction, process isolation, domain separation, resource encapsulation, information hiding, simplicity, least privilege, layering, modularization, and minimization. Achieving each principle is believed to enhance security in some respect.

For the sake of simplicity, we can categorize the first cyber principles into two sets: network and system. The network category includes domain separation, layering, resource encapsulation, and minimization. **Domain separation** is a mechanism to protect one functionality, task, or data from interfering with another to enforce security and protection. Similarly, **layering** encourages us to build multiple levels of defense to ensure resilience against attack. **Resource encapsulation** is another cybersecurity first principle that enables manipulation of resources only as intended by the resource owners to prevent unauthorized access. Lastly, from a cybersecurity point of view, the goal of **minimization** is to reduce the number of possible attack vectors, such as by turning off unused ports and unnecessary features. The system category includes abstraction, process isolation, least privilege, simplicity, modularization, and information hiding. From a software engineering point of view, **abstraction** is a design principle that enforces the minimization of unnecessary clutter from a system that can distract and possibly lead to complexity, which could make the system difficult to manage. **Process isolation** is a mechanism that enables systems to execute on the same platform without interfering with one another. **Least privilege** advocates a strategy of assigning minimum but sufficient power to manage system resources by ensuring correct operation, security, and protection. On the other hand, **simplicity of design** promotes the reduction of unnecessary details to in an effort to accomplish a reliable and secure system. **Information hiding** enforces secure coding by requiring programmers to expose only the necessary functions to external applications. Lastly, **modularity** emphasizes separation of functionality to enhance code security and protection. Overall, the first principles of cybersecurity are designated as the fundamental concepts of the GenCyber curriculum. A solid understanding of the first principles of cybersecurity is important to produce talented individuals for cybersecurity industry and government roles.

Research Objectives

The purpose of this research is to evaluate the impact of a representative GenCyber training program on students' future career paths. The GenCyber summer program aims to grow the future generation of computer science experts in general, and cybersecurity professionals in particular. The main goal of this research is to explore the impact of a GenCyber training program on the interest of K-12 students toward STEM fields, specifically in the area of computer science and cybersecurity. In addition, this research also evaluates its impact in addressing gender parity between boys and girls in their future career interests. Based on the above, this research identifies the following two questions: first, would participating in the GenCyber summer program impact K-12 students' interest in future STEM careers? And second, would participating in the GenCyber summer program minimize students' gender bias toward future STEM careers? The objective is to gain further information about factors that contribute to the underrepresentation of girls in STEM career pathways. The remainder of this paper is organized as follows: In section 2, related works relevant to this research are presented. Section 3 discusses the methodology used for this research. Section 4 presents the experimental results. Finally, a discussion of the results and their implications, and the conclusion, are presented in section 5.

RELATED WORK

Various studies have explored a number of models in their attempt to explain at what time in a person's life their career interest emerges, how it develops and matures, and how volatile or persistent the choice may be over time (Bandura, 1986; Coley, 2010; Crissey, 2009; Fouad 2007; Gibons, 2004; Lent, Brown, & Hackett, 1994). For instance, Boni et al. associated career choice with five aspects of learning: empathy (willingness to try new ideas, tools), integrative thinking (thinking outside the box), optimism (I believe I can do it), experimentation (let's experiment with this), and collaboration (ability and willingness to working with others) (Agogino 2007; Boni, Arthur, Laurie, & Shelley, 2009; Li 1999). On the other hand, the Social Cognitive Career Theory (SCCT) defines interest as a person's "pattern of likes, dislikes and indifferences" with regard to a particular field or subject matter (Lent & Brown, 2006). For instance, the SCCT attempted to explain the reason behind how people develop a specific career interest, how they reach a decision on making career choices, and how they deal with obstacles that hinder them form achieving their career goals (Lent, Brown, & Hackett, 1994). Overall, SCCT stated that career interests are potentially determined and regulated by self-efficacy, outcome expectations, and goals (Bandura, 1986; Christensen, Knezek, & Tyler-Wood, 2015; Gibons, 2004[Lent et al., 1994; Sadler et al., 2012).

Self-efficacy refers to an individual's attitude about their ability to successfully complete an assigned task. It is influenced by cognitive, social and situational factors. On the other hand, outcome expectations refer to the perceived results, either positive or negative, obtained from performing certain tasks. Finally, an individual's goals could depict the final decision as to whether to begin a particular career path. Particularly, research suggests that students would develop career interest in a particular field if the subject is engaging, if they feel that they possess personal competency and will experience positive outcomes. However, if they feel that they have low personal competency, they will tend to shy away from a particular career path. Therefore, barriers such as bias due to gender or ethnicity could create negative impacts on career interests. Overall, students' ability to self-categorize themselves as future STEM professionals is vital in shaping their success in achieving their career goals. This self-empathy (the is the act of giving oneself empathy, and optimism (positivity and confidence about oneself) could make a difference in shaping their college performance such as choosing a STEM major, persisting in their majors, and completing their college degree. Improving these contributing factors could considerably enhance the STEM pipeline. Therefore, school counsellors, family members, community leaders, and government officials should work hand-in hand in creating a conducive environment to encourage and engage students in STEM courses early and often throughout their education and training.

METHODS

Participants

The National Cyber Warrior Academy (NCWA) is a national cybersecurity awareness and ethical cyber operations training program based on the GenCyber framework, aimed to enhance interest in cybersecurity careers and help students understand how to protect themselves from cybercriminals. It is a two-week, residential cyber camp with over 80 hours of instruction, including more than 40 hours of hands-on labs in the area of computer science and cybersecurity. The academy is geared toward students interested in cybersecurity studies, and is expected to enhance the interest of high school sophomores, juniors and seniors in STEM-related careers. Participant recruitment took three main forms: printed brochures mailed to 212 high school principals in the university's 32-county service area, emails sent to over 2,000 high school advisement counsellors and instructors in the southeast region, and a program website and press releases from institutional university relations staff disseminated electronically. The majority of the applications received were from in-state applicants, primarily in the university's traditional 32-county service area, but a number of out-of-area and out-of-state students also applied.

Sample Characteristics

The program staff reviewed all 137 applications received and ranked the applications based on merit: by grade point average (GPA), students' self-reported computer interest as demonstrated by a written essay and student experience with computing or involvement in extra-curricular computing activities (programming, robotics, or cyber competition teams or related clubs). Due to the university's emphasis on global engagement and strategic languages, priority consideration was given to students with experience or proficiency in a Department of Defense (DoD) strategic language including Arabic, Mandarin Chinese, Dari, Hindi, Korean, Portuguese, Persian, Russian, Turkish, Swahili, and Urdu. The effect size of 0.5 was used to estimate the size of the participants using G*Power (Erceg-Hurn, & Vikki, 2008; Faul et.al, 2007; López et. al., 2015). Forty applicants with an average weighted GPA above 3.8, and highly diverse, with 24 males and 16 females (60% male, 40% female) were selected for the training program. As shown in Fig. 1, 55% students who self-identified as Caucasian, 20% as Asian, 12.5% as African American, and the remaining 10% as mixed ethnic groups, respectively. With regard to age, as expected all participants were between the ages of 14 and 17. More than 92% of the participants were between the ages of 15 and 17 while the remaining three (7%) were aged 14.

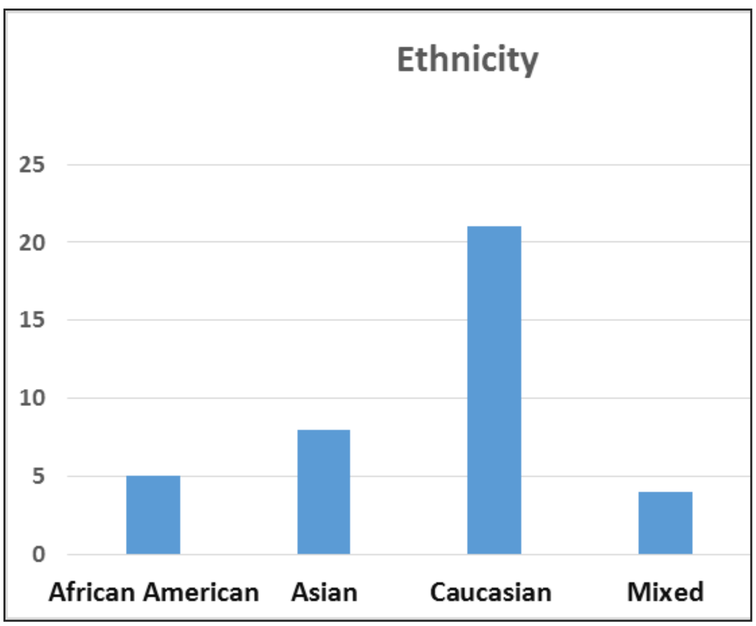


Figure 1. Ethnicity Distribution

Protocol and materials

NCWA GenCyber program began with parents dropping off students. Upon arrival, the participant was greeted, his or her identity was verified, and parents signed various release forms, including consent to participate in the IRB-approved research study. Once the researchers verified the parental consent form, then the PreGenCyber survey questionnaire was provided to the participants. This questionnaire was targeted to collect background information from the participant directly and to capture the career interest of the participants prior to attending the GenCyber summer training program. In addition, participants were asked to self-rate their computer science and cybersecurity skills before and after the GenCyber training program on a scale from 1 (less proficient) to 6 (extremely proficient). A copy of the informed consent document and STEM career interest questionnaire was provided to each participant upon request. After the participant completed the survey, he or she was then thanked and escorted to their living quarters by cadet counsellors. Each day of instruction, students participated in physical recreation activities before breakfast, not at the level of physical readiness training (PRT) for the Corps of Cadets, but enough to get their blood flowing and prepare their minds and bodies for intensive cyber training all day long. Class began at 9 AM, with lunch from 12-1 PM, lab instruction from 1-5 PM, followed by dinner and two to three hours of planned evening activities, including guest speakers and group activities such as drone programming, Sphero robot activities, car-hacking, 3D printing, capture-the-flag exercises, and NAO robotics.

The primary curriculum for the program consisted of the EC-Council's Certified Ethical Hacker (CEH) training material, specifically, the hands-on labs (EC-Council, 2016). The CEH curriculum consists of 18 modules, from hacking individual operating systems to web servers to mobile devices, and from cryptography to cloud computing to social engineering. The core focus of CEH is to look for weaknesses and vulnerabilities to assess the security of target systems and the lab manual includes over 700 pages of step-by-step security and vulnerability testing labs, with dozens of additional lab activities available through the EC-Council web portal. In addition, each day, one of the ten first principles was discussed in detail. In addition, students were asked to come up with a 3D printed object to embody each of the cyber first principles, and they used 3D printers to produce the objects and gave a presentation to help their fellow students understand why the particular object represented that concept or principle. Team-building activities were woven throughout the program. Finally, a PostGenCyber training survey questionnaire was given to the students before they left the academy.

Hardware and software

VMWare running nine virtual machines (Kali, Ubuntu and various Windows OS versions) from the CEH curriculum plus instructor-supplied materials served as the primary workstations. A wide variety of open-source and free software tools were used including Oracle VirtualBox VM, Kali/Metasploit, Wireshark, Snort, OpenGarages, and many more. The mini drones used for the drone programming/hacking exercises were Parrot Mini Cargo Drones (six total). The Sphero robot orbs (five total) were loaned to the program from one of the schools we partner with. The NAO robot was used for the last full evening of elective activities (owned by the computer science department). And, the 3D printers (three total) were XYZ Corp. Da Vinci Jr. 1.0W printers. All of these hardware items were in place before the GenCyber program, and are used in multiple programs at the university. A field trip to Georgia Tech Research Institute's (GTRI) security operations center (SOC) in Atlanta on the Saturday between the two weeks of instruction was conducted to enable students see real-time and aggregated information across ten 60-inch monitors in the unclassified level of GTRI's SOC.

Design

The experimental data points were collected using pre- and post-training surveys with a scale from 1 (less interested) to 6 (extremely interested). The data analysis in the study employs different categories of mixed factorial design. Each design includes gender & ethnicity as the between-subject design. Together with gender and ethnicity, two categories of future career interest were identified and investigated: STEM (STEM careers and computer science) and non-STEM (medical and social sciences). In addition, participants were also asked to self-rate their computer science area proficiency before and after the training. This was mainly used to capture their perceived leaning and self-confidence in perusing STEM careers. Based on the above description, five two-way mixed ANOVA factorial design analyses were conducted. Each factorial design is described in section 4 together with the analysis result.

RESULTS

As reported in section 3, five two-way mixed ANOVA factorial design analyses were conducted. Participants were asked to rate their future career interest in STEM, non-STEM, and computer science and cybersecurity related fields. In addition, participants were asked to self-rate their computer science and cybersecurity skills before and after the GenCyber summer program on a scale of 1 (less proficient) to 6 (extremely proficient). We predicted that GenCyber training would improve proficiencies in the area of computer science and related fields. Based on previous studies, we also predicted that there would be gender and ethnicity differences in computer proficiency ratings.

A preliminary analysis of ethnicity as a between-subject factor revealed no significant main or interaction effect, so it was omitted from further consideration. Therefore, this study was adjusted as a 2 (GenCyber training: PreGenCyber and PostGenCyber) by 2 (Gender: female and male) two-way, mixed analysis of variance (ANOVA) factorial design. The self-rated values are treated as numbers and the mean value was used instead of the median for better analysis as suggested by (David M & Mirosevich) to represent ratings of the participants for a given condition. ANOVA was used to analyse the statistical significance of each of the conditions.
The hypothesis, data analysis, and results are presented in the following subsequent sub-sections.

1. Impact of GenCyber training on future STEM career interest: data analysis and result

The hypothesis of the study of the impact of GenCyber training on future STEM career interest is stated as “GenCyber training enhances future career interest in STEM and related fields”. The first IV (independent variable) is gender, which includes two values: female and male. The second IV (i.e., GenCyber training) contains two conditions: PreGenCyber (baseline) and PostGenCyber training. The dependent variable (DV) is future career interest rating. The descriptive statistics of the influence of early computer science training on early future career interest in STEM field are provided in Table 1-1. It can be seen from Table 1-1 that the overall mean for future STEM career interest for females and males before and after the training are 24.53, 28.83, 23.00, and 29.13 respectively. This shows that the training shows an increase in career interest ratings for the male gender category. However, the mean STEM career interest for females before and after the training shows that the training has a negative impact for females. This is not consistent with the researchers' prediction. Further analysis was needed to determine the statistical significance of the means. As indicated, a two-way mixed ANOVA was performed to compare the effect of early GenCyber training on future STEM career interest of the participants. The result of the analysis is presented in Table 1-2.

Table 1-1. Descriptive Statistics of STEM career interest rate

GenCyber training	Gender	Mean	Std.Dev
PreGenCyber	Female	24.53	9.15
PreGenCyber	Male	28.83	5.65
PostGenCyber	Female	23.00	8.67
PostGenCyber	Male	29.13	7.60

As presented in Table 1-2, the analysis indicated there was no statistically significant difference either in the main effect of GenCyber training, $F(1, 37)=0.341$, $p>0.05$, or as an interaction effect between GenCyber training and gender, $F(1,37)=0.736$, $p>0.05$, on future career interest. Meanwhile, the result indicated that there is a statistically significant main effect of gender on future career interest, $F(1,37)=5.280$, $p(0.027)<0.05$, $\eta p2 =0.125$. However, the effect size was 0.125, which means that the effect of gender difference accounted for 12.5% of the between-group differences, suggesting that the impact of gender on future career interest is relatively minimal.

Table 1-2. Two-Way Mixed ANOVA for STEM career interest rate

Source of Variance	SS	df	MS	F	P(Sig)	η_p^2
GenCyber training	7.116	1	7.116	.341	.563	.009
Error (GenCyber training)	772.346	37	20.874			
Gender	501.603	1	501.603	5.280	.027*	.125
Error (Gender)	3515.346	37	95.009			
GenCyber training * Gender	15.372	1.000	15.372	.736	.396	.020
Error (GenCyber training * Gender)	772.346	37	20.874			

Note: SS=Sum of Square, MS=Mean Square, Result of 2 (GenCyber training : PreGenCyber, PostGenCyber) × 2 (Gender:Female, Male)

Figure. 2 presents the plot of the comparisons of estimated mean differences in future career interest ratings in the STEM fields by gender and GenCyber training. In general, GenCyber training has mixed impact on gender-based future career interest. Specifically, the plot in Figure. 2. shows that the GenCyber training program improves future STEM-related career interest for males. However, this pattern did not hold true for females.

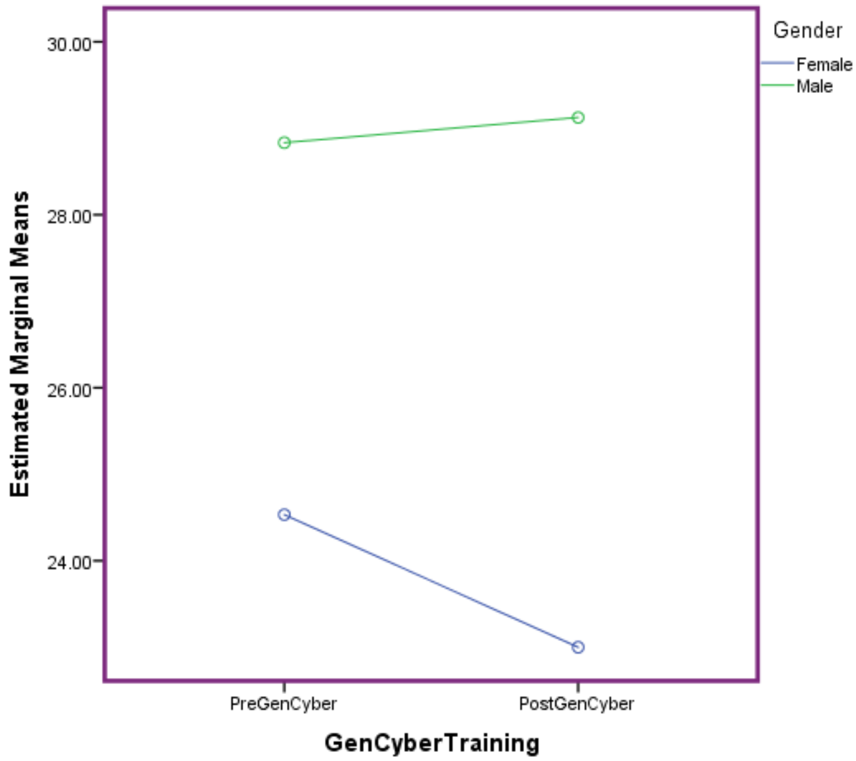


Figure 2 Estimated means for future STEM career interest of GenCyber training for each gender category.

2. Impact of GenCyber training on future Computer Science and Cybersecurity career interest: data analysis and result

The descriptive statistics of the influence of GenCyber training on future career interest in computer science and related fields is provided in Table 2-1. It can be seen from Table 2-1that the overall mean for future career interest in computer science before and after training for both females and males are 4.0, 4.87, 5.12, and 5.38 respectively. This shows that the training increases interest for the female gender group. Further analysis was needed to determine the statistical significance of the means. Early results were consistent with our prediction. Additional data analysis was required to investigate the statistical significance of each of the conditions. As stated, a two-way mixed ANOVA was used to analyse the statistical significance of the impact of GenCyber training on future computer science and cybersecurity career interest.

Table 2-1. Descriptive Statistics of Computer Science career interest rate

GenCyber training	Gender	Mean	Std.Dev
PreGenCyber	Female	4.00	1.77
PreGenCyber	Male	5.12	1.19
PostGenCyber	Female	4.87	1.36
PostGenCyber	Male	5.38	1.06

Table 2-2 presents the analysis results for the effects of GenCyber training on future career interest in computer science and cybersecurity. The analysis provides interesting findings for computer science career interest ratings for GenCyber training and gender categories. In addition, the result showed that there was no statistically significant difference in the interaction between GenCyber training and gender, F(1,37)=1.619, p>(.211)>0.05. However, the result indicated that there were statistically significant difference of main effect for both GenCyber training, F(1,37)=5.308, p (0.027)<0.05, ηp2=.125, and gender category, F(1,37)=5.185, p (0.029)<0.05, ηp2=0.123. Overall, the results indicated that there was a statistical difference between gender and GenCyber training on the future career interest in computer science and cybersecurity. However, the effect of gender and GenCyber training differences accounted for 12.5% (for gender) and 12.3% (for GenCyber training), suggesting that the impacts of both gender and GenCyber training in future career interest in computer science and related fields are relatively minimal.

Table 2-2. Two-Way Mixed ANOVA for computer science and related fields career interest rate

Source of Variance	SS	df	MS	F	P(Sig)	η_p^2
GenCyber training	5.755	1	5.755	5.308	.027*	.125
Error (GenCyber training)	40.117	37	1.084			
Gender	12.313	1	12.313	5.185	.029*	.123
Error (Gender)	87.867	37	2.375			
GenCyber training * Gender	1.755	1	1.755	1.619	.211	.042
Error (GenCyber training * Gender)	40.117	37	1.084			

Note: SS=Sum of Square, MS=Mean Square, Result of 2 (GenCyber training: PreGenCyber, PostGenCyber) * 2 (Gender: Female, Male

Figure. 3 shows the plot for the comparisons of estimated mean differences in future career interest rate in computer science and related fields by gender and GenCyber training. Overall, the plot in Figure. 3 shows that for GenCyber training program improves the future computer science and cybersecurity-related career interest for both females and males. This pattern is consistent with our predictions.

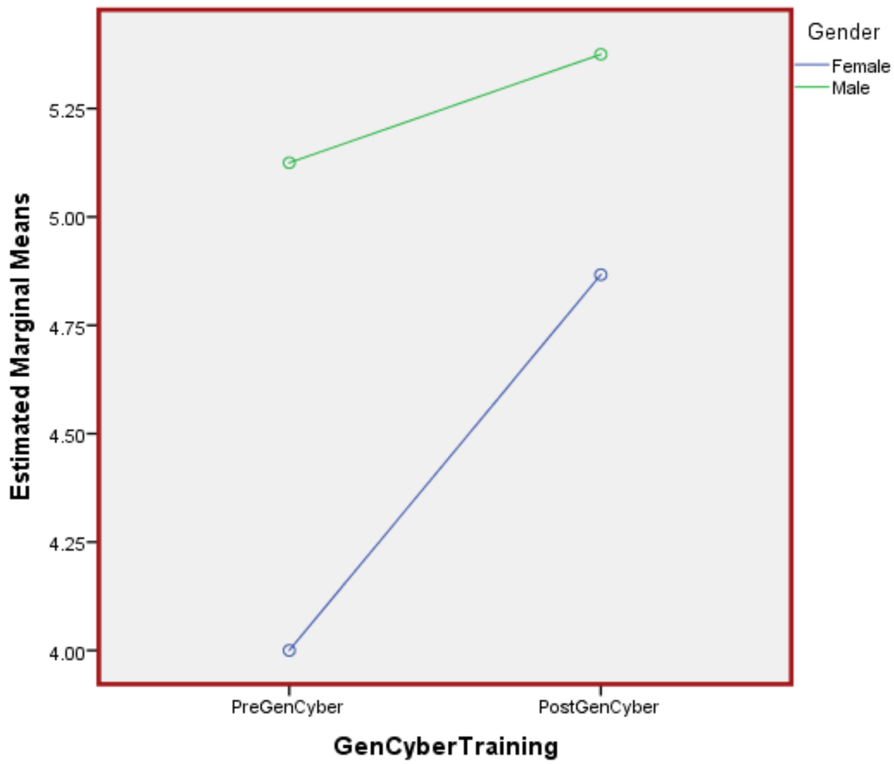


Figure 3. Estimated means for future computer science career interest of GenCyber training for each gender.

3. Impact of GenCyber training on future medical career interest: data analysis and result

The hypothesis for the impact of GenCyber training on future medical career interest is that GenCyber training enhances future career interest rate in medical and related fields and medical career interest rate as a dependent variable. The research is geared toward answering the following hypotheses: GenCyber training decreases future career interest rate in medical fields. The analysis result is presented in Table 3-1. It can be seen from Table 3-1 that the overall mean for future medical career interest for females and males before and after the training are 5.53, 5.13, 4.08, and 4.29 respectively. This shows that the training has a decrease in interest rate for female participants. However, the overall mean medical career interest for males before and after the training show that the training has a positive impact. Further analysis was needed to determine the statistical significance of the means. As indicated, a two-way mixed ANOVA was performed to compare the effect of early GenCyber training on future medical career interest of the participants.

Table 3-1. Descriptive Statistics of GenCyber of Medical career interest rate

GenCyber training	Gender	Mean	Std.Dev
PreGenCyber	Female	5.53	2.85
PreGenCyber	Male	4.08	1.77
PostGenCyber	Female	5.13	2.47
PostGenCyber	Male	4.29	2.20

The analysis results showed that there was no statistically significant differences in main effect of GenCyber training $F(1,37)=0.77$, $p>0.05$, and main effect of gender $F(1,37)=2.985$, $p>0.05$. Similarly, the interaction results indicated that there was no significant interaction effects gender and GenCyber training on future medical career interest impact, $F(1,37)=0.773$, $p>0.05$. Overall, the result indicated that there was no significant difference between GenCyber training and gender in influencing future medical career interest.

4. Impact of GenCyber training on future social career interest: data analysis and result

Likewise, the hypothesis of the impact of GenCyber training on future non-STEM (social) career interest is that GenCyber training enhances future career interest in non-STEM (social studies) and related fields. Similar to the medical career interest described in section 4.3, a preliminary analysis including Ethnicity as a between-subject factor revealed no significant main or interaction effects, so it was omitted from further consideration. Therefore, this study is adjusted as a 2 by 2, mixed factorial design ANOVA with two independent variable (IV). The first IV is gender, which includes two levels: female and male. The second IV (i.e., GenCyber training) contains two conditions: baseline (pre-training) and post-training. The dependent variable (DV) is future social science career interest level.

As can be seen from Table 4-1, the overall mean for future social career interest ratings for females and males before and after the training are 20.47, 18.80, 19.79, and 19.83 respectively. This shows that the training induces a decrease in interest rate for female participants. However, the overall mean social career interest for males before and after the training shows that the training has a positive impact for males. Further analysis was needed to determine the statistical significance of the means. As indicated, a two-way mixed ANOVA was performed to compare the effect of early GenCyber training on future social career interest of the participants. The result of the analysis is presented in Table 4-1.

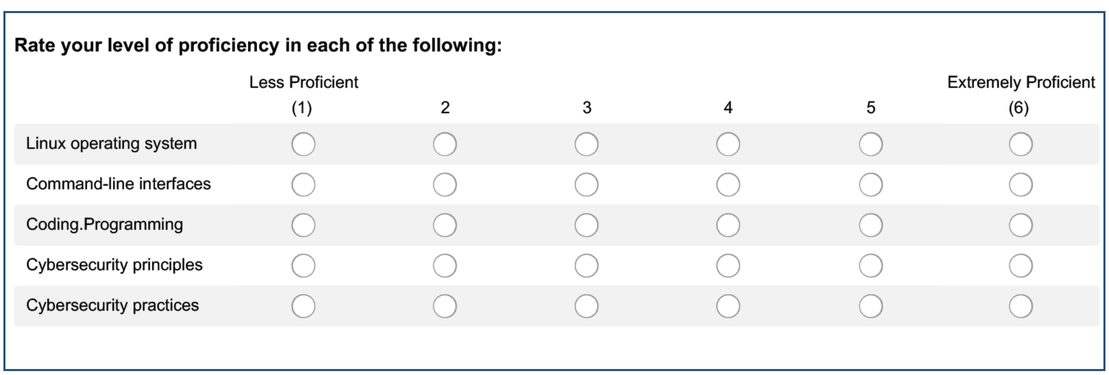
Table 4-1. Descriptive Statistics GenCyber of Social Science career interest rate

GenCyber training	Gender	Mean	Std.Dev
PreGenCyber	Female	20.47	7.54
PreGenCyber	Male	19.79	4.60
PostGenCyber	Female	18.80	5.77
PostGenCyber	Male	19.83	5.95

The analysis results showed that there was no statistically significant difference in main effects for both gender and GenCyber training $F(1,37)=0.776$, $p>0.05$, and $F(1,37)=0.11$, $p>0.05$, respectively. Similarly, the interaction results indicated that there was no significant interaction effects among gender and GenCyber training on future social science career interest, $F(1,37)=0.11$, $p>0.05$. Overall, the result indicated that there was no significant difference between GenCyber training and gender in influencing the future social science career interest.

5. Impact of GenCyber training on self-rating proficiency in computer science and related fields: data analysis and result

The hypothesis of the impact of GenCyber training on self-rated proficiency in computer science and related fields is stated as, "GenCyber training improves self-rated proficiency in computer science and related fields." Figure 4. presents the self-rating proficiency questionnaire. It includes various technical areas in computer science and cybersecurity fields. The descriptive statistics of the influence of GenCyber training on self-rated proficiency in computer science and related fields is provided in Table 5-1. It can be seen from Table 5-1 that the overall mean for proficiency in computer science and related fields for females and males before and after the training are 7.04, 21.88, 13.88, and 20.15 respectively. This shows that the training has an increase in self-rated proficiency ratings for both female and male gender categories. This is consistent with our prediction. Further analysis was needed to determine the statistical significance of the means. As indicated, a two-way mixed ANOVA was performed to compare the effect of early GenCyber training on participants' self-rated proficiency. The result of the analysis is presented in Table 5-2. As presented in Table 5-2 shows that the mean user proficiency ratings for both gender categories follow a similar pattern in that GenCyber training enhances perceived proficiency in computer science and related fields for both females and males. Early result is consistent with our prediction. Further data analysis is required to find out the statistical significance of each of the conditions of GenCyber training and gender.


Rate your level of proficiency in each of the following:

	Less Proficient (1)	2	3	4	5	Extremely Proficient (6)
Linux operating system	○	○	○	○	○	○
Command-line interfaces	○	○	○	○	○	○
Coding.Programming	○	○	○	○	○	○
Cybersecurity principles	○	○	○	○	○	○
Cybersecurity practices	○	○	○	○	○	○

Figure 4. PreGenCyber and PostGenCyber training on computer perceived proficiency self-ratings

Table 5-2 presents the results for the effects of GenCyber training on future career interest in computer science and cybersecurity related fields. The analysis provides interesting findings for computer science career interest ratings for GenCyber training and gender categories. As shown in Table 5-2, the analysis results of the level of perceived proficiency in computer science and cybersecurity related fields indicated that there was no statistical interaction effect between GenCyber training and gender, F(1,37)= 1.380, p(.248)>0.05. However, the result indicated that there were statistically significant difference of main effect for both GenCyber training, F(1,37)= 111.776, p <0.0001, ηp2 =.751, and the gender category, F(1,37)= 12.048, p (0.001)<0.05, ηp2 =0.246. Moreover, with respect to GenCyber training, the effect size of 0.751, which means that the effect of GenCyber training difference accounted for 75.1% of the group-differences, suggesting that the impact of GenCyber training on self-rating proficiency in computer science and related fields is relatively high. However, with respect to gender, the effect size of 0.246, which means that the effect of gender difference accounted for 24.6% of the group-differences, suggesting that the impact of gender on self-rating proficiency in computer science and related fields is relatively low.

Table 5-1. Descriptive Statistics of computer science and related field self-rated proficiency

GenCyber training	Gender	Mean	Std.Dev
PreGenCyber	Female	7.40	3.70
PreGenCyber	Male	13.88	6.83
PostGenCyber	Female	21.88	4.72
PostGenCyber	Male	20.15	5.42

Table 5-2. Two-Way Mixed ANOVA for computer science self–rated proficiency

Source of Variance	SS	df	MS	F	P(Sig)	η_p^2
GenCyber training	1495.385	1	1495.385	111.776	.000	.751
Error (GenCyber training)	495.000	37.000	13.378			
Gender	553.396	1	553.396	12.048	.001	.246
Error (Gender)	1699.450	37	45.931			
GenCyber training * Gender	18.462	1	18.462	1.380	.248	.036
Error (GenCyber training * Gender)	495.000	37.000	13.378			

Note: SS=Sum of Square, MS=Mean Square, Result of 2 (GenCyber training : PreGenCyber, PostGenCyber) × 2 (Gender: Female,

Figure. 5 shows the plot of the comparisons of estimated mean differences in self-rated proficiency in computer science and related fields by gender and GenCyber training. In general, the plot in Figure. 5 shows that for GenCyber training program improves the perceived computer science skills of the participants. This pattern is consistent with our hypothesis.

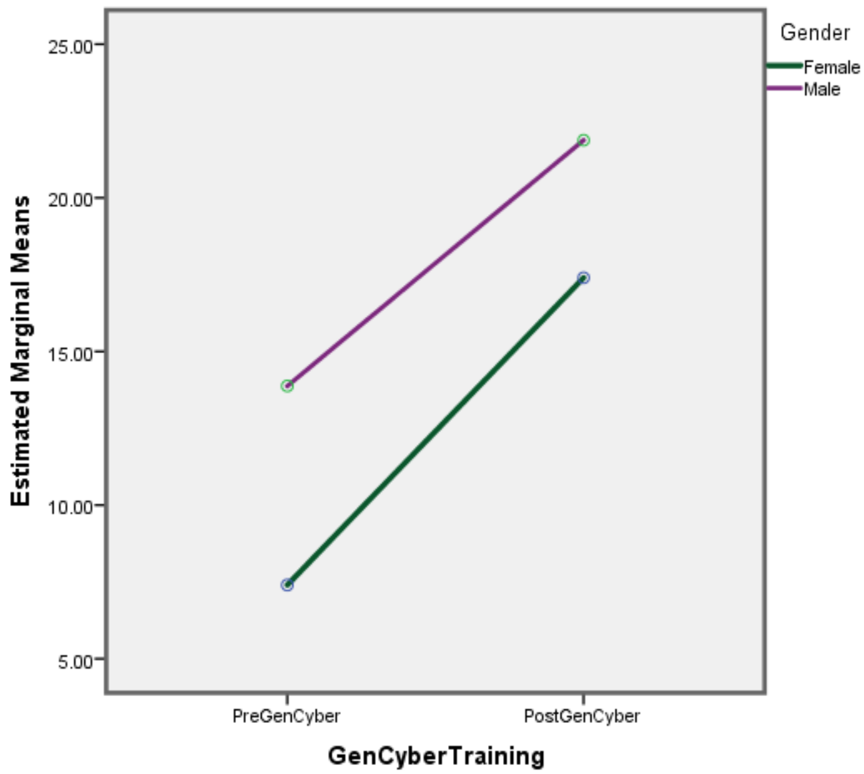


Figure 5. Estimated means for self-rated computer/cyber proficiency of GenCyber training for each gender category

DISCUSSION & CONCLUSION

Recently, most developing and developed countries have realized that STEM is tomorrow's most demand-driven career field for sustainable global economic growth. From the US perspective, various governmental and non-governmental agencies are working hand-in hand to prepare students for careers in STEM-related fields. As an important initiative, the GenCyber program was established as a framework to inspire and prepare young US citizens in an effort to fill the critical shortage of current and future experts in the constantly evolving field of cybersecurity. This research aims to evaluate the influence of the GenCyber training program on students' future career interest in STEM, cybersecurity, computer science, & related fields. In addition, recent studies indicate that although women represent roughly half of the entire US population, they represent less than a quarter (24%) of the nation's STEM workforce (Department of Commerce, August 2011). Given this disproportionately low number of females participating in STEM-related fields, it is the responsibility of society to encourage and provide the necessary assistance to citizens of all genders and ethnic origins to pursue STEM education. Therefore, this study also attempted to evaluate the GenCyber program's impact on minimizing the gender disparity between high school boys and girls in their future career interests.

The research identified the following two questions: first, would participating in the GenCyber summer program impact K-12 students' interest in future STEM careers? And second, would participating in the GenCyber summer program minimize students' gender bias toward future

STEM careers? As part of this study, forty high school rising sophomores to rising seniors were recruited to participate in the two-week residential National Cyber Warrior Academy (NCWA). While the ten first cybersecurity principles are conceptual ideas designed as the foundation of the GenCyber curriculum, students were given more practical, engaging, and intensive technical training in computer science and cybersecurity. Therefore, this study attempted to measure the effect of hands-on technical training on self-rated proficiency in the areas of computer science and cybersecurity. The experimental data was collected using pre- and post-training surveys. The analysis examined different categories via mixed factorial design.

A preliminary analysis including ethnicity as a between subject factor revealed no significant main or interaction effects, so it was omitted from further consideration. Consequently, this study was adjusted as five 2 by 2 repeated measures factorial design ANOVAs. Participants were asked to self-rate their interest in STEM, non-STEM, computer science and cybersecurity on a scale from 1 (less interested) to 6 (extremely interested). In addition, participants were asked to self-rate their computer science and cybersecurity skills before and after the GenCyber training program on a scale from 1 (less proficient) to 6 (extremely proficient).

Major findings were: a) GenCyber training program improves the future STEM-related career interest for males. However, the overall mean STEM career interest for females before and after the training shows that the training has a negative impact for females. This is not consistent with our prediction. b) The GenCyber training program improves the future computer science and cybersecurity related career interest for both females and males. Specifically, the findings indicated that GenCyber training improved career interest specifically in the area of computer science and cybersecurity for both genders. c) The training improved their self-rated proficiency in computer science and related fields for both females and males. d) Finally, the analyses indicated that there was no significant difference across GenCyber training and gender in influencing participants' future career interest in non-STEM careers. This tends to show that the GenCyber training didn't make a significant impact in deterring interest in non-STEM fields.

Overall, the results of this research suggest that GenCyber training could reasonably improve students' interest, skills, and proficiency in the field of computer science and cybersecurity, as well as their perceived efficacy in these areas of study. Given the increasing prevalence of cyber-threats in various governmental and non-governmental organizations, and the resultant economic, strategic, and security challenges to our society, the federal and private sectors seek large numbers of qualified cyber professionals with the requisite knowledge, skills, and abilities to protect the nation. Most importantly, this effort is particularly helpful to protect the nation from some of our most sophisticated adversaries and to safeguard our sensitive political and technological data, our financial and business systems, and other critical infrastructure. As a whole, expanding cybersecurity education by reaching out to primary and secondary school systems to simulate interest in computer science and cybersecurity-related fields, through initiatives such as the GenCyber program, will help fulfill the increasing demand for a greater cyber workforce. While the program has a positive impact on two significant factors in future career choices, tremendous effort is required to reach to the expected results in a one-camp-at-a-time approach. It is equally important to note that more significant changes are needed in both academic and societal culture in the US to attract more girls into STEM-related fields to minimize the gender gap. As part of future-work, we are planning to reach out to the participants and investigate if attending GenCyber has a long-lasting impact.

REFERENCES

Agogino, A. (2007, April). Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering. In APS April Meeting Abstracts (Vol. 1, p. 6001).

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Prentice-Hall, Inc.

Bloom, B. S. (1956). Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. New York: David McKay Co Inc.

Boni, A. A., Weingart, L. R., Evenson, S. (2009). Innovation in an academic setting: Designing and leading a business through market-focused, interdisciplinary teams. *Academy of Management Learning & Education 8*(3), 407-417.

Certified Ethical Hackers, EC-Council (2016). Retrieved from https://www.eccouncil.org/programs/certified-ethical-hacker-ceh/#

Chen, X. (2013). STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences, U.S.Department of Education. Washington, DC.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Gender differences in high school student dispositions toward science, technology, engineering, and mathematics careers. *Journal of Computers in Mathematics and Science Teaching, 34*(4), 395-408.

Clark Blickenstaff*, J. (2005). Women and science careers: leaky pipeline or gender filter?. *Gender and education, 17*(4), 369-386.

Coley, C., & Coley, T. (2010). Retention and student success: Staying on track with early intervention strategies. Sungard Higher Education.

Crissey, S. (2009). Educational attainment in the United States: 2007 (No. P20-560). US Census Bureau. Retrieved from http://www.census.gov/prod/2009pubs/p20-560.pdf

Dark M., & McNair B. (2015). *GenCyber Evaluation Report,*

Department of Commerce, (2011, August). Women in STEM: A Gender Gap to Innovation.

Erceg-Hurn, D. M., & Mirosevich, V. M. (2008). Modern robust statistical methods: an easy way to maximize the accuracy and power of your research. *American Psychologist 63*(7), 591.

Executive Office Of The President Office Of Management And Budget Washington, D.C. 20503 (2016, July 12) Retrieved from https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-15.pdf

Faul F., Erdfelder E., Lang A. G., & Buchner A. G (2007, May 1). *Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods, 39*(2),175-91.

Fouad, N. A. (2007). Work and vocational psychology: Theory, research, and applications. *Annu. Rev. Psychol., 58*, 543-564.

Frome, P. M., & Eccles, J. S. (1998). Parents' influence on children's achievement-related perceptions. *Journal of personality and social psychology, 74*(2), 435.

Furnham, A., Reeves, E., & Budhani, S. (2002). Parents think their sons are brighter than their daughters: Sex differences in parental self-estimations and estimations of their children's multiple intelligences. *The Journal of genetic psychology, 163*(1), 24-39.

GenCyber Spring Meeting, San Francisco, May 14-15, 2016.

Gibbons, M. M. (2004). Prospective first-generation college students: Meeting their needs through social cognitive career theory. *Professional School Counseling, 8*, 1, 91-97.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494-495.

Lehming, R. F., Alt, M. N., Chen, X., Hall, L., Burton, L., Burrelli, J. S., & Moris, F. A. (2010). Science and Engineering Indicators 2010. NSB 10-01.National Science Foundation.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of vocational behavior, 45*(1), 79-122.

Lent, R. W., & Brown, S. D. (2006). On conceptualizing and assessing social cognitive constructs in career research: A measurement guide. *Journal of career assessment*, *14*(1), 12-35.

Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: A review. *Educational Research*, *41*(1), 63-76.

López, X., Valenzuela, J., Nussbaum, M., & Tsai, C. C. (2015, December 15). Some recommendations for the reporting of quantitative studies. *Computers & Education, 91*(C),106-10.

Marzano, R. J. (2004). Building background knowledge for academic achievement: Research on what works in schools. Alexandria, VA: ASCD.

Mau, W. C. (2013). STEM career aspirations of high school students: A social-cognitive perspective, paper presented at the annual meeting of Association for Institutional Research, Long Beach, CA.

Mau, W. C. J. (2016). Characteristics of US Students That Pursued a STEM Major and Factors That Predicted Their Persistence in Degree Completion.

Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments: Special issue on interactive learning environments: Contemporary issues and trends. *Educational Psychology Review, 19*(3), 309-326. doi:10.1007/s10648-007-9047-2

National Academy of Sciences, Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering (National Academies Press, Washington, DC, 2006).

National Research Council. (2011). Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics

National Science Foundation (2012). Science and Engineering Indicators 2012. Arlington VA: National Science Foundation (NSB 12-01). Retrieved from http://www.nsf.gov/statistics/seind12/pdf/seind12.pdf

National Science Foundation (2013). Women, Minorities, and Persons with Disabilities in Science and Engineering, Arlington, VA: National Science Board (NSF 13-304). Retrieved from http://www.nsf.gov/statistic s/wmpd/2013/start.cfm

Program Director Guide (2016), Generation of Cyber Stars (GenCyber)

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411-427.

U.S. Department of Education. (2006). A Test of Leadership: Charting the Future of U.S. Higher Education. Washington, DC.

Wang, M. T., Eccles, J. S., & Kenny, S. (2013). Not lack of ability but more choice individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychological Science*, *24*(5), 770-775.

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