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Toward a Student-Ready Cybersecurity Program: Findings from a Survey of STEM-Students

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Toward a Student-Ready Cybersecurity Program: Findings from a Survey of STEM-Students

Abstract

As the number of available cybersecurity jobs continues to grow, colleges strive to offer to their cybersecurity students an environment which will make them sufficiently prepared to enter the workforce after graduation. This paper explores the academic and professional needs of STEM-students in various higher education institutions across Virginia and how cybersecurity programs can cater to these needs. It also seeks to propose an evidence-based approach for improving the existing cybersecurity programs so that they can become more inclusive and student-ready. A survey of 251 college students in four higher-education institutions in Virginia showed that while there are common patterns observed across gender and race, there are still areas in which more should be done regarding some of these groups. In particular, some discrepancies are observed across gender when it comes to students' preparation with business fundamentals, the overall satisfaction of the received STEM education, and across race and ethnicity, when it comes to college advising, peer-mentoring, tutoring and faculty mentoring. The results from this study inform specific recommendations that will bring higher-education institutions and their cybersecurity program to a more student-ready level.

Cover Page Footnote

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Keywords

cybersecurity, advising, tutoring, mentoring, student success

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INTRODUCTION

For many years, the prevalent understanding about the relationship between colleges and students was that students should be prepared for the college experience and the majors they will pursue. However, the K-12 education does not offer equal conditions to all students, and neither do the individual circumstances of the students and their families. Tia McNair and her colleagues (2014) develop the idea of the "student-ready college" which does not focus on expectations for students but instead creates the environment in which they will thrive. The authors emphasize that "a student-ready college is one that strategically and holistically advances student success and works tirelessly to educate all students for civic and economic participation in a global, interconnected society" (McNair et al., 2014).

While this is a proper categorization of the goals that all fields of study should have, this notion is particularly relevant to the growing field of cybersecurity. Statistics show that the cybersecurity workforce demand is very high and the supply – low. This is especially true for Virginia, among other states such as California, Florida, New York, North Carolina, and Texas, where the total job openings for cybersecurity specialists are the highest in the U.S. (CyberSeek, 2021). Along with the notable need for cybersecurity professionals, there is also an evident need for diversity – women are only 14% of the entire cybersecurity workforce and African Americans make up only 3% of the people engaged in the information security sector (Must, 2021). As institutions prepare to diversify the cybersecurity pipeline, a question that arises is whether differences exist in terms of underrepresented students' needs and perceptions about cybersecurity education. To address this question, this study focused on students' assessment of their own cybersecurity skills, and various academic services, designed to increase student success. We also explored whether there are any variations across race, gender and major. Addressing this topic will help to determine how to make cybersecurity educational programming "ready" for students.

In particular, this paper contributes to better understanding the STEM-students coming to cybersecurity programs in Virginia, who they are, what the level of their preparation is, what academic services can help them be successful, and what are the obstacles they encounter on the path to graduation. The results from the study will assist in focusing on the students' needs as a way to enhance cybersecurity programs and make them more appealing, inclusive, accessible, and fulfilling.

LITERATURE REVIEW

The cybersecurity workforce is under-employed (Legg, 2021) and exhibits a tendency to become even more so, considering the low number of college graduates who decide to pursue a degree with which they can work in the field of cybersecurity. Steven T. Kroll provides an interesting example that underscores the urgent need for a rapid change within the education system when it comes to cybersecurity. He states that if, of the 3.6 million high-school graduates in 2019, 66% go to college and only 3% of them choose to major in computer science and a cybersecurity-related discipline, the shortage of specialists in cybersecurity, estimated in 2021 to be 2.72 million worldwide ((ISC)^2 Cybersecurity Workforce Study, 2019), will become even more serious than it currently is (Kroll, 2019). Furthermore, according to data from the National Center for Education Statistics (2021), the six-year graduation rate for full-time students at four-year higher education institutions between 2012 and 2018 was 62%. To make this issue even more complicated, there is also a lack of diversity within the cybersecurity workforce which can be traced back to obstacles underprivileged groups, such as first-generation students, low-income students, and women in STEM encounter. A study by Rebecca Stout and colleagues (2018) found that there is a positive correlation between the graduation rates of students from minority groups and faculty diversity within the higher-education institution. This can also serve to bolster the idea of empowerment when it comes to representation and role-models within the academic environment, and even beyond. While some general findings point to an increase in retention and graduation rates if all students are more academically prepared, receive scholarships and other financial help and are a part of smaller-classes (Millea et al., 2018), there are some specific characteristics of minority student-groups that also need to be considered when discussing the topic of a student-ready college campus.

Gender. For women, various roadblocks may exist on the pathway to becoming a cybersecurity expert. Some authors suggest that the issue with gender equality in the STEM fields begins in middle school – 46.2% of the middle-school girls were enrolled in technology-related courses – a percent that dramatically drops to 8.6% when the same issue is revisited in high school (Mitts, 2008). This tendency could be explained by various factors, including, but not limited to the lack of female role-models occupied in science, technology, engineering, and math (STEM) fields (Herrmann et al., 2016). The lack of women in cybersecurity is particularly troubling in light of the fact that female college students have slightly higher graduation rates than their male counterparts and they are also just as dedicated users of smart technology as their male counterparts (Mitts, 2008). Among the other reasons for women dropping out of STEM-courses and majors is

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the sense of not belonging to the field, also exacerbated by the aforementioned lack of female instructors and peers, but also the perception of the masculine stereotype of the profession itself (Cheryan et al., 2009). In addition, a survey of the women in cybersecurity found that women are disinterested in joining or remaining in the cybersecurity workforce because of the social expectations of the profession, associated with late nights and long-hours which may prevent them from their obligations, as women remain predominantly responsible for childcare and housework (Bagchi-Sen et al., 2010).

As the evidence shows, not only do women gradually drop out of STEM-courses and careers, but when they remain in the field, they are also likely to be paid less. Citing a study of the cybersecurity workforce ((ISC)^2 Cybersecurity Workforce Study, 2019), Phil Muncaster highlighted that on average, women in cybersecurity are paid 21% less than men, with the average salary for women in cybersecurity in North America being under $80,000 and for men around $96,500 (Muncaster, 2020). In addition, women can be excluded or disadvantaged in a job search process due to implicit biases of hiring managers (Alms, 2022). Jobs for which AI algorithms are used can further limit the number of women and minorities in cybersecurity, as they use the pattern of previous successful candidates for the job, which are mostly men, to search for new ones, thus excluding women and minorities (O'Neil, 2018).

Concentrated state, federal and private funding, and efforts for increasing diversity over the years produced some positive results for the total number of women in the workforce between 2013 (11%) and 2019 (20%), despite their share still being far too insufficient (Morgan, 2019). However, diversity should be understood not only as a quantitative characteristic, but as a qualitative one. Michael Lang and his colleagues (2022, p. 4) argue that it is a recognition of "nationality, ethnicity, religious beliefs or non-beliefs, age, socio-economic status, professional background, and prior learning" and "the intersectionality of individuals and the role that they play" in the field of cybersecurity. This argument could be relevant for both academic programs and the workforce in general. Hence, higher education institutions and government and private employers need to focus on creating and maintaining an environment which will retain talent of women and other minorities.

Race. Statistics show that in the field of cybersecurity, non-white races and ethnicities are severely underrepresented (Zippia, 2021). The workforce relies predominantly on white professionals (72.6%), followed by much less represented people of other races – Asian (9.6%), Black/African American (7.4%), Hispanic/Latino (7.1%), American Indian and Alaska Native (0.4%) and others (2.9%). This further proves that the lack of diversity spreads from the already discussed minority groups (women, first-generation college students and low-income students) to cybersecurity talent from non-white races and ethnicities. The problem is exacerbated further when cross-sections of different minority groups are considered as well as projections envisioning an increase in the minority population of the U.S. that could reach 50% by 2050 (Palmer et al., 2010). To improve the conditions for different minority groups, particularly women of color, scholars recommend a comprehensive plan including efforts from high-school guidance counselors to develop cybersecurity curricula and proper advising to mentoring, scholarships and internships in the students' college years (Burrell & Nobles, 2018).

Advising. The importance of successful advising is highlighted in various scholarly works as its meaning extends beyond the transition from high school to college and can take many forms, especially in a period in which information is increasingly distributed digitally. In particular, there are programs that assist students with financial aid issues, exploration of colleges, and shaping their intellectual curiosity into a long-term career plan (Schneider et al., 2013), while feeling supported by their academic counselors (Rozhenkova, 2022), as this supports the trust they have in the institution in general (Harper & Thiry, 2022). In cases of at-risk and underrepresented groups, some researchers recommend intrusive advising strategies that put an accent on the problem as soon as one arises. Under this model students are prescribed a strategy to resolve the issue through presenting the educational process as a collaboration between an individual student and advisor (Heisserer & Parette, 2002). Such strategies and programs are correlated with higher retention rates (Rodgers et al., 2014). Other authors suggest an in-classroom community college advising strategy by STEM faculty in which pathways to a four-year degree are discussed (Packard et al., 2013). A study, based on interviews with STEM community college students interested in transferring identifies some of the obstacles that they encounter on the path to getting a four-year degree. The findings show that deficits in the information shared or the inclusion of misleading information during advising sessions impedes student progress as the transfer process could become more time-consuming, stressful, and costly (Packard & Jeffers, 2013). At times, the issues with advising are produced by other factors, especially in rural areas. Grimes and colleagues (2019) interviewed school counselors and inquired about the barriers that they face in providing productive advising. Among them are lack of resources, innovation and interpersonal influence and relationships (Grimes et al., 2019). Another set of interviews of women in STEM community college programs underlined some of the difficulties they encounter after transferring to a four-year institution and the reasons some of them did not pursue further STEM education – "negative course experiences, poor advising, and limited finances…[lack of] a helpful professor or advisor in a STEM field…and family responsibilities", (Packard et al., 2011, p. 129).

Mentoring. The role of faculty and peer mentoring in STEM, particularly for underrepresented groups in the field is also a well-researched scholarly area. A group of researchers documented the success of a STEM faculty mentoring program in a historically black college or university (HBCU), examining in-depth the relationship between mentorship and increased student success (Kendricks et al., 2013). One innovative faculty mentoring approach focuses on underrepresented students' self-reflection on the barriers for success and sources of encouragement on the way to completing their STEM degree (Chelberg & Bosman, 2019). In another study about tools for success in STEM, research mentorship also proved to be effective, especially in cases in which the students saw a demographic resemblance with their mentor or some shared beliefs (Atkins et al., 2020). Scholars also underscore the importance of STEM faculty mentors to create the right academic and social environment based on trust and guidance for their mentees, particularly those of color (Griffin et al., 2010; Griffin et al., 2020). For instance, Sweeney Windchief and Blakely Brown study the obstacles that American Indian/Alaska Native students in STEM encounter in terms of mentorship. The author concludes that a productive implementation of mentoring for American Indian/Alaska Native students should integrate academic mentoring into the Indigenous culture and its manifestations (Windchief & Brown, 2017). Another group of researchers emphasizes the importance of specialized training for mentors so that they can help their mentees be successful in the STEM sector (Stelter et al., 2021).

Along with faculty mentoring, peer mentoring is also proven to contribute to the success of STEM students in college. A team of researchers linked peer mentoring and satisfaction with the selected major, commitment to completing their degree and a desire for the mentee to become a mentor (Holland et al., 2012). An intriguing experiment turned potential mentees into mentors themselves. This near-peer mentoring model included undergraduate and postgraduate mentors to students in grades 6-12. Tenenbaum and colleagues (2014) describe the outcomes for the mentors as beneficial in regard to their professional development, academic preparation, and their level of maturity (Tenenbaum et al., 2014).

Tutoring. Another strategy with the potential for increasing student success is tutoring. Some authors view it as a useful tool in the education process, others see it as having less-to-no value, and even possibly harmful for the tutored student, and a third group of researchers emphasize the conditions under which tutoring can be a productive activity (Hock et al., 1999). One of these conditions can potentially pertain to the tutoring style. Peng and Wu (2021) conduct a study comparing two tutoring methods – directive and facilitating. Their analysis shows that there are no statistically significant differences between the two styles when it comes to learning satisfaction and perception of the STEM tutoring process (Peng & Wu, 2021).

Other scholars examine the topic of tutoring with more innovative approaches. Shy, Northern and Brown (2008) outline the value of cognitive-developmental approaches to teaching mathematical theories that are aimed to increase the level of comprehension through “concept discussions, highly enforced problem application, peer-peer subgroups, and constructive learning-centered activities” (Shy et al., 2008 p. 13). Griffith and Griffith (2017) demonstrate how a tutoring software, based on AI predictions showing information to the learner for which it considers them ready, can also increase calculus and trigonometry scores of students. Other similar tutoring products incorporate a dashboard for the teachers to assist students who are having a difficult time executing the tasks they are asked to complete (Dickler, 2019).

The issue of attracting and retaining talent from lower socio-economic backgrounds, first-generation students, women, and other minorities in STEM should be occupying the attention of different institutions, organizations, and society in general. While researchers agree that the cybersecurity pipeline needs to be diversified (Mountrouidou et al., 2019) and certain student support strategies promote student success (Consolvo, 2002), research is needed to determine whether student demographic characteristics impact perceptions about skills and reactions to student support initiatives. In this study, the following two research questions are addressed: (1) Are there gender and racial differences in cybersecurity students’ ratings of skills?; and (2) Are there gender and racial differences in the types of student support activities defined as helpful?

The process of improving the conditions for these underprivileged groups starts as early as elementary school and continues through the different stages of the cybersecurity career. While this study will focus on the needs of the cybersecurity college student, the findings need to be situated within the broader context of limitations and opportunities that the K-12 system and the professional field of cybersecurity offer collectively. We aim to determine what is needed to build a “student-ready” cybersecurity program - one which will replace high expectations of students with a solid level of preparation so that they can thrive academically.

RESEARCH DESIGN

The research question of this study is: How can the conditions for cybersecurity students in higher education institutions be improved, especially for minority students, thus addressing first, the lack of cybersecurity professionals, and second, the lack of diversity in the field? Aiming to better understand the experiences of current and the needs of potential incoming cybersecurity students, a survey was administered to students (N=251) enrolled in three community colleges and one four-year institution in Virginia. These institutions have collaborated to develop articulation agreements for students who want to transfer from the community college to the four-year institution for cybersecurity. Students may enter cybersecurity majors from a variety of fields thus students in various STEM majors were included in the recruitment efforts. The 251 respondents were asked questions in four categories, including: 1) the number of cybersecurity courses taken and the level of interest in taking non-STEM courses; 2) self-assessment of the level of preparation with skills, important for a career in cybersecurity – teamwork, planning and organizing, creative thinking, problem-solving and decision-making, working with tools and technology, business fundamentals; 3) importance of advising, peer-mentoring, faculty-mentoring, tutoring for student success; 4) likelihood of completing the degree at the current higher education institution and potential or existing obstacles to completing it. Students were asked questions 2 to 4 in the form of a scale in which they showed a level of agreement to the provided statement. They had the opportunity to respond with strongly agree, agree, disagree, and strongly disagree. In order to aggregate the results, some of them were grouped into two categories - “strongly agree” and “agree”, on the one hand, and “disagree” and “strongly disagree”, on the other. The data were analyzed and presented using descriptive statistics and crosstabulations.

RESULTS AND ANALYSIS

In the following section, we will discuss the results from the survey and contextualize the findings. The latter starts with a description of the characteristics of the STEM-students in Virginia and in particular, their age, gender, race/ethnicity, course delivery method, residence, major, and number of cybersecurity classes taken so far. The subsequent sections seek to gain insight into their college experiences and if they vary across these characteristics.

Characteristics of the STEM-Students in Virginia. The surveyed STEM-students from Virginia range from age 18 to 63, as Table 1 shows. The relatively higher maximum age of the students can be explained by the fact that there are professionals who had a career related to cybersecurity and are looking to receive an official document certifying their previously gained skills and expanding them to fit the requirements of the cybersecurity sectors (federal, state, and local, and private). Another possible explanation for the upper age limit is that many military professionals are seeking to add to their current practical experience skills related to cybersecurity technical writing. Universities in Virginia are an attractive educational environment for military personnel because of the high number of military installations in the state. For example, data from the Virginia Department of Education show that in 2019, the number of military-connected students in the public schools of the Commonwealth is approximately 80,000 (Virginia Department of Education, 2021) – some of the highest, nationwide.

Table 1. Descriptive statistics: STEM students by age, gender, race/ethnicity, course delivery method, residence, and number of taken cybersecurity courses

	Minimum	Maximum
Age (N=241; Mean = 25.46)	18	63
***		
Gender (N=246)	N	%
Women	90	36.6
Men	153	62.2
Non-binary	3	1.2
***		
Race/Ethnicity (N=238)	N	%
White	116	48.7
Black/African American	63	26.5
Asian	28	11.2
Hispanic	17	7.1
American Indian/Alaska Native	2	0.8
Native Hawaiian/Pacific Islander	1	0.4
Multiracial	11	4.6
***		
Course delivery method (N=248)	N	%
On campus	187	75.4
Online	51	20.6
Other	10	4
***		
Residence (N=250)	N	%
In-state student	240	96
Out-of-state student	7	2.8
International student	3	1.2
***		
Major (N=251)	N	%
Cybersecurity	122	48.6
Other STEM majors	129	51.4
Number of taken cybersecurity courses (N=231)		%
No cybersecurity classes	87	37.7
1-5 cybersecurity courses	103	44.7
6-10 cybersecurity courses	32	13.8
11-15 cybersecurity courses	7	3
More than 15 cybersecurity courses	2	0.8

Regardless of the higher upper maximum of the students' age, the average age of the STEM-students in Virginia is much lower – approximately 25 years. This indicator reveals that predominantly young people enter STEM-programs and efforts by multiple institutions and organizations and on multiple levels are needed to retain these people in the same field.

The survey results point to a negative tendency already shown in the literature – that the number of male students is much higher than that of women. The relative proportion of the male to female students is approximately 3:5. While more attention is being paid to make cybersecurity a more welcoming field for women, their numbers remain low relative to the number of their male counterparts. Compared to the numbers of both men and women, non-binary students remain a much lower number. Special measures need to be adopted in the K-16 system and beyond – to not only retain the interest of non-binary students in cybersecurity but to create the material and non-material conditions for them to thrive academically and professionally.

When it comes to race and ethnicity, the findings from the survey, summarized in Table 1c, also indicate a troubling discrepancy between the number of students from different races/ethnicities enrolled in STEM-programs. The number of Black/African American students (N=63) is nearly twice as low as the number of the white students (N=116). At the same time, the number of Asian students (N=28) is almost twice as low as the number of Black/African American students. The number of Hispanic students (N=17) and the students identifying themselves as multiracial (N=11) are similar but higher than the number of American Indian/Alaska Native (N=2) and Native Hawaiian/Pacific Islander (N=1) students. Regardless that these results overall correspond to such from previous studies already described in this paper, they should be considered with caution, because of the relatively small sample sizes in the survey. One notable difference in these results has to be mentioned as well. The proportion of Black/African American students in the survey is much higher than the proportion of Black/African American professionals engaged in the cybersecurity workforce. This finding outlines the need for retention of such students and the creation of an academic environment where they will not only remain in college but will graduate and find equitable employment opportunities similar to their white peers.

In terms of course delivery method, the majority of the respondents take their courses primarily on-campus, as opposed to online. The number of the on-campus students is more than three times higher than the number of those online. This proportion invites two questions with potentially alternative responses which may be explored in further studies. First, do students prefer to take all or most of their classes on-campus and second, are colleges – both community and 4-year institutions - offering a sufficient number of online courses to satisfy the needs of their students? Expectedly, as described in Table 1, the number of in-state students (N=240) is much higher than the number of out-of-state students (N=7) and international students (N=3). However, the same two questions can be asked for this section of the results as well – do the low numbers of out-of-state and international students indicate that they want to attend institutions in their home states/countries or that they want to attend an institution outside of their state/home country, but either experience material or/and non-material obstacles being physically present on-campus or being online students? These questions suggest the need for further studies, using interviews and focus-groups so that the findings from our study are specified and contextualized.

The number of surveyed students seems to be equally distributed across cybersecurity and other STEM majors. Regarding the students' preparation in the field of cybersecurity, the results from Table 1 show that on average, students took two or three cybersecurity courses by the time the survey was conducted. While this is definitely positive news for the level of interest of STEM-students in cybersecurity, the more detailed picture of these results suggests some potentially disturbing tendencies. More than half of the surveyed STEM-students took some cybersecurity courses. However, the largest group of STEM-students is the one who took between one and five cybersecurity courses. The number of STEM-students who took no more than five cybersecurity courses is significantly higher than the number of students who took more than five courses and then it decreases further for more than ten cybersecurity courses and more than fifteen. This finding should also be placed in the context of the number of cybersecurity courses offered by an institution. It is possible that the students were interested in taking more cybersecurity courses, but they were not offered by their institution, especially considering that most of them were community colleges and not 4-year degree-granting institutions. If this is the case, it becomes crucial that policies and strategies pave the way for community college STEM-students to have the opportunity to transfer to a 4-year institution and continue their cybersecurity education. There are increased efforts in this direction exemplified in the transfer and articulation agreements between 4-year institutions and community colleges in Virginia (Virginia Community College System, 2021). Regardless, the pathways to a 4-year degree for cybersecurity students need to be further solidified by investing more resources into making a smooth transition for community college students.

Further breakdown of this category's results by gender, race, and major can be consulted through Table 2, as they do not reveal any aberrant patterns.

Table 2. Number of cybersecurity courses taken by gender, race, and major

	0	1-5	6-10	11-15	15+
By gender					
Chi-square=10.23; df=17; sig.=0.89					
Women (N=85)	36 (42.4%)	34 (40%)	12 (14.1%)	2 (2.4%)	1 (1.2%)
Men (N=139)	47 (33.8%)	66 (47.5%)	20 (14.4%)	5 (3.6%)	1 (0.7%)
Total (N=224)	**85 (37.4%)**	**101 (44.5%)**	**32 (14.1%)**	**7 (3.1%)**	**2 (0.9%)**
By race					
Chi-square=24.5; df=24; sig.=0.43					
White (N=107)	46 (43%)	47 (43.9%)	10 (9.3%)	2 (1.9%)	2 (1.9%)
African American (N=57)	22 (38.6%)	23 (40.4%)	11 (19.3%)	1 (1.8%)	0
Asian (N=27)	9 (33.3%)	10 (37%)	6 (22.2%)	2 (7.4%)	0
Hispanic (N=17)	1 (5.9%)	13 (76.5%)	2 (11.8%)	1 (5.9%)	0
American Indian/ Alaska Native (N=2)	1 (50%)	0	1 (50%)	0	0
Native Hawaiian/ Pacific-Islander (N=1)	1 (100%)	0	0	0	0
Multiracial (N=10)	4 (40%)	5 (50%)	1 (10%)	0	0
Total (N=221)	**84 (38%)**	**98 (44.3%)**	**31 (14%)**	**6 (2.7%)**	**2 (0.9%)**
By major					
Chi-square=133.27; df=17; sig.=0.001					
Cybersecurity (N=112)	3 (2.7%)	70 (62.5%)	30 (26.8%)	7 (6.3%)	2 (1.8%)
Other STEM majors (N=119)	84 (70.6%)	33 (27.7%)	2 (1.7%)	0	0
Total (N=231)	**87 (37.7%)**	**103 (44.6%)**	**32 (13.9%)**	**7 (3%)**	**2 (0.9%)**

Level of Interest in Taking Courses Outside of Students' Major. The next question of the survey asked STEM-students to indicate to what extent they are interested in taking other courses outside of their major degree program. The results overwhelmingly point to the conclusion that students are interested in doing so – more than half of the respondents (74.4%) strongly agree and agree that they want to take such courses. This finding is consistent across gender, race, course delivery method and residence (see Table 3). The calls for interdisciplinary approaches to teaching cybersecurity are not new to the literature (Craigen et al., 2014; Jacob et al., 2020; LeClair et al., 2013; Payne et al., 2021). The responses of the STEM-students only confirm the need for interdisciplinarity as the field itself is international and complex, and its problems interconnected and related to both technical and social science skills.

Table 3. Level of interest in taking courses outside of students' major

	Strongly Agree	Agree	Disagree	Strongly Disagree
By gender				
Chi-square=0.49; df=3; sig.=0.92				
Women (N=53)	15 (28.3%)	25 (47.2%)	11 (20.8%)	2 (3.8%)
Men (N=71)	17 (23.9%)	34 (47.9%)	16 (22.5%)	4 (5.6%)
Total (N=124)	32 (25.8%)	59 (47.6%)	27 (21.8%)	6 (4.8%)
By race				
Chi-square=9.05; df=15; sig.=0.88				
White (N=65)	17 (26.2%)	31 (47.7%)	15 (23.1%)	2 (3.1%)
Non-white (N=59)	17 (28.8%)	28 (47.5%)	10 (16.9%)	4 (6.8%)
Total (N=124)	**34 (27.4%)**	**59 (47.6%)**	**25 (20.2%)**	**6 (4.8%)**
By major				
Chi-square=1.95; df=3; sig.=0.58				
Cybersecurity (N=120)	43 (35.8%)	48 (40%)	23 (19.2%)	6 (5%)
Other STEM majors (N=129)	36 (27.9%)	60 (46.5%)	27 (20.9%)	6 (4.7%)
Total (N=249)	**79 (31.7%)**	**108 (43.4%)**	**50 (20.1%)**	**12 (4.8%)**

Self-Assessment of the Level of Preparation with Skills, Important for a Career in Cybersecurity. The survey that was conducted as part of this study also asked STEM-students to evaluate their preparation with skills, considered important to the field of cybersecurity and other STEM fields, namely, teamwork, planning and organizing, creative-thinking, problem-solving and decision-making, working with tools and technology, and business fundamentals. It should be mentioned that the survey inquired about the self-assessment of the students rather than their actual preparation with these skills, which may be different than their assessed level. Regardless, the vast majority of the respondents feel very or at least somewhat prepared with these skills. In particular, 95% of the respondents (N=251) feel very or somewhat prepared to do teamwork, 93% of them feel confident in their planning and organizing skills, 91% - in their creative thinking skills, 95% in their problem-solving and decision-making skills, 90% - in working with tools and technology, and 68% feel prepared in the area of business fundamentals. While all of these rates are very high, the last one indicates where more work can be done by educational institutions and other cybersecurity stakeholders. Table 4 illustrates the level of preparation with these skills by gender, race, and major. A careful examination of the results shows that they are almost evenly distributed across these categories. One of them – preparation with business fundamentals per gender - deserves some more attention. According to the data from our survey, female students feel much less prepared in this area than their male counterparts – 38% of the female respondents stated that they are not well or not at all prepared, as opposed to 28% of the male students sharing such concerns. These gender differences are also troubling in light of the fact that 19% of the surveyed female students assess their college experience in the STEM majors as worse and much worse than expected than the male students (16%). The comparison across gender does not reveal any significantly different results or a correlation between the variables, but it still requires measures aimed at creating a more equitable and nurturing environment for women interested in cybersecurity in the K-16 system and afterwards. In terms of the results by major, cybersecurity students seem to express slightly more confidence in having mastered certain skills, as opposed to their peers from other STEM majors.

Importance of Advising, Peer-Mentoring, Faculty-Mentoring, Tutoring for Student Success. The survey also sought to explore student opinions regarding some campus resources and services. The respondents were asked to assess each of four different services and their role in college success. Interestingly, advising was the only category whose importance all groups in Table 5 below shared (63% or higher, who rated it very or somewhat important), highlighting it as a means to their college success. The only exception is the few respondents identifying themselves as Native American/Alaska Natives, but the small sample size of this group of students may have led to this result. To be more specific, the convincing agreement across groups also has nuances. For instance, some races/ethnicities see advising as a more important element for their college success than others – 62% of the white students, 67% of the Black/African American students, 61% of the Asian students, 52% of the Hispanic, and 82% of the ones identifying themselves as Multiracial.

Other university services and resources did not enjoy the level of agreement among students that advising did. However, there are some discrepancies in terms of race and course delivery method that should be discussed. Peer-mentoring appears to be much more significantly related to college success for Black/African American students (48%) than for white students (28%), Hispanic (29%) and Asian

Table 4. Levels of feeling prepared vs. unprepared in important cybersecurity skill areas

	Teamwork	**Planning & Organizing**	**Creative Thinking**	**Problem-solving & Decision-making**	**Working with Tools & Technology**	**Business Fundamentals**
By gender						
	Chi-square=1.07; df=1; sig.=0.3	*Chi-square=1.38; df=1; sig.=0.24)*	*Chi-square=2.22; df=1; sig.=0.4*	*Chi-square=0.47; df=1; sig.=0.83*	*Chi-square=0.47; df=1; sig.=0.23*	*Chi-square=2.7; df=1; sig.=0.1)*
Women	83 (92.2%) v. 7 (7.8%)	85 (95.5%) v. 4 (4.5%)	79 (87.8%) v. 11 (12.2%)	85 (95.5%) v. 4 (4.5%)	77 (86.5%) v. 12 (13.5%)	56 (62.2%) v. 34 (37.8%)
Men	146 (95.4%) v. 7 (4.6%)	140 (91.5%) v. 13 (8.5%)	141 (93.4%) v. 10 (6.6%)	147 (96.1%) v. 6 (3.9%)	139 (91.4%) v. 13 (8.6%)	110 (72.4%) v. 42 (27.6%)
Total:	**229 (94.2%) v. 14 (5.8%)**	**225 (93%) v. 17 (7%)**	**220 (91.3%) v. 21 (8.7%)**	**232 (95.9%) v. 10 (4.1%)**	**216 (89.6%) v. 25 (10.4%)**	**166 (68.6%) v. 76 (31.4%)**
By race						
	Chi-square=0.4; df=1; sig.=0.85	*Chi-square=0.12; df=1; sig.=0.73*	*Chi-square=0.01; df=1; sig.=0.93*	*Chi-square=0.24; df=1; sig.=0.63*	*Chi-square=0.9; df=1; sig.=0.77*	*Chi-square=1.32; df=1; sig.=0.25*
White	110 (94.8%) v. 6 (5.2%)	107 (92.2%) v. 9 (7.8%)	104 (90.4%) vs. 11 (9.6%)	110 (95.7%) v. 5 (4.3%)	104 (90.4%) v. 11 (9.6%)	73 (63.5%) v. 42 (36.5%)
Non-white	115 (94.3) v. 7 (5.7%)	113 (93.4%) v. 8 (6.6%)	109 (90.1%) v. 12 (9.9 %)	115 (94.3%) v. 7 (5.7%)	108 (89.3%) v. 13 (10.7%)	86 (70.5%) v. 36 (29.5%)
Total:	**225 (94.5%) v. 13 (5.5%)**	**220 (92.8%) v. 17 (7.2%)**	**213 (90.3%) v. 23 (9.7%)**	**225 (94.4%) v 12 (5.1%)**	**212 (89.8%) v. 24 (10.2%)**	159 (67.1%) v. 78 (32.9%)
By major						

	Chi-square=10.1; df=1; sig.=0.001	*Chi-square=5.4; df=1; sig.=0.02*	*Chi-square=4.87; df=1; sig.=0.27*	*Chi-square=0.24; df=1; sig.=0.63*	*Chi-square=0.002; df=1; sig.=0.97*	*Chi-square=8.93; df=1; sig.=0.003*
Cybersecurity	120 (99.2%) v. 1 (0.8%)	117 (96.7%) v. 4 (3.3%)	113 (95%) v. 6 (5%)	117 (96.7%) v. 4 (3.3%)	108 (90%) v. 12 (10%)	92 (76.7%) v. 28 (23.3%)
Other STEM majors	116 (89.9%) v. 13 (10.1%)	114 (89.1%) v. 14 (10.9%)	112 (86.8%) v. 17 (13.2%)	120 (93.8%) v. 8 (6.3%)	115 (89.8%) v. 13 (10.2%)	76 (58.9%) v. 53 (41.1%)
Total:	**236 (94.4%) v. 14 (5.6%)**	**231 (92.8%) v. 18 (7.2%)**	**225 (90.7%) v. 23 (9.3%)**	**237 (95.2%) v. 12 (4.8%)**	**223 (89.9%) v. 25 (10.1%)**	**168 (67.5%) v. 81 (32.5%)**

* The results in each cell represent the number of students who feel somewhat prepared and very prepared vs. the students who feel not well unprepared or not at all prepared in skills important for the cybersecurity profession.

Table 5. Students' assessment of the importance of university programs and resources for college success

	Advising	**Peer-mentoring**	**Faculty-mentoring**	**Tutoring**
By gender				
	Chi-square=4.14; df=1; sig.=0.04	*Chi-square=0.9; df=1; sig.=0.34*	*Chi-square=0.02; df=1; sig.=0.9*	*Chi-square=0.07; df=1; sig.=0.8*
Women	63 (70%) v. 27 (30%)	27 (30%) v. 63 (70%)	36 (40%) v. 54 (60%)	38 (42.2%) v. 52 (57.8%)
Men	87 (56.9%) v. 66 (43.1%)	55 (35.9%) v. 98 (64.1%)	60 (39.3%) v. 93 (60.8%)	62 (40.5%) v. 91 (59.5%)
Total	**150 (61.7%) v. 93 (38.3%)**	**82 (33.7%) v. 161 (66.3%)**	**96 (39.5%) v. 147 (60.5%)**	**100 (41.2%) v. 143 (58.8%)**
By race				
	Chi-square=0.09; df=1; sig.=0.77	*Chi-square=3.14; df=1; sig.=0.08*	*Chi-square=1.23; df=1; sig.=0.27*	*Chi-square=1.94; df=1; sig.=0.16*
White	72 (62.1%) v. 44 (37.9%)	33 (28.4%) v. 83 (71.6%)	50 (43.1%) v. 66 (56.9%)	42 (36.2%) v. 74 (63.8%)
Non-white	78 (63.9%) v. 44 (36.1%)	48 (39.3%) v. 74 (60.7%)	44 (36.1%) v. 78 (63.9%)	55 (45.1%) v. 67 (54.9%)
Total:	**150 (63%) v. 88 (37%)**	**81 (34%) v. 157 (66%)**	**94 (39.5%) v. 144 (60.5%)**	**97 (40.8%) v. 141 (59.2%)**
By major				
	Chi-square=0.05; df=1; sig.=0.83	*Chi-square=1.56; df=1; sig.=0.21*	*Chi-square=7.2; df=1; sig.=0.01*	*Chi-square=0.08; df=1; sig.=0.79*
Cybersecurity	75 (61.5%) v. 47 (38.5%)	45 (36.9%) v. 77 (63.1%)	58 (47.5%) v. 64 (52.5%)	49 (40.2%) v. 73 (59.8%)
Other majors	81 (62.8%) v. 48 (37.2%)	38 (29.5%) v. 91 (70.5%)	40 (31%) v. 89 (69%)	54 (41.9%) v. 75 (58.1%)
Total:	156 (62.2%) v. 95 (37.8%)	83 (33.1%) v. 168 (66.9%)	98 (39%) v. 153 (61%)	103 (41%) v. 148 (59%)

* The results represent the number of students who agree/strongly agree vs. the students who disagree/strongly disagree

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students (29%). Another intriguing result that was observed pertains to tutoring and its role in college success, as assessed by the respondents. This category is mentioned as much more important for Black/African American students (52%) and Hispanic students (47%) than for white and Asian students (36%). As for faculty-mentoring, there are also some differences in the results. This form of faculty support was notably rated more important for Hispanic students and Multiracial students (47%) than for white students (42%), Black/African American students (35%) and Asian students (29%). Further examination of this question may be beneficial in determining whether the personality of the faculty members themselves plays a role in the level of student interest in this service. The results in this category by major seem to be equally distributed across cybersecurity and students from other STEM degrees. The only interesting difference pertains also to faculty mentoring, as it seems to be much more important for cybersecurity students and less for such from other STEM majors.

Likelihood of Completing the STEM-degree at the Current Higher Education Institution and Related Obstacles. Most of the surveyed STEM-students indicate that it is very (77%) or somewhat likely (17%) that they will finish their degree at their current higher education institution. This is in sharp contrast to the percent of students (only 6%) who state that they are not very or not at all likely to complete their current degree at their former institution. However, among the goals of every higher education institution needs to be to eliminate the number of students who are unable to complete their degree. To provide context to this goal, we also asked the surveyed STEM-students, who were unlikely to finish their degree at their current institution, what would prevent them from doing so. Some of the obstacles that the students mention pertain to time-management, inability to keep up with coursework because of full-time jobs, accumulating loans, not getting hands-on skills, and lack of time to compensate for content not well explained by professors in class. These impediments can be transferred into recommendations that will make STEM and cybersecurity programs more student-ready. What can assist in this regard is: 1) providing more scholarships and financial opportunities for students to complete their degree to reduce the need to work full-time, including programs and resources that will reduce the students' overall expenses; 2) provide an in-person or/and online advising course regarding time-management during college; 3) maximize the benefits that the course content offers while the student is in class or while the student is engaged in the learning process online, so that the extra time needed to complete coursework is reduced and the student is exposed to new content and has the opportunity to practice skills within a certain amount of time, traditionally allocated for a class period (approximately two or three hours per week for undergraduate students); 4) increased investment in experiential learning programs in cooperation with cybersecurity companies and units within the federal and local government.

CONCLUSION

In this study, we aimed to analyze the experiences of STEM-students in the context of cybersecurity. Our goal was to provide concrete directions in which cybersecurity programs can be improved so that they are more accommodating, inclusive, and helpful to students. While the core goal of this project was to deliver evidence-based recommendations about college cybersecurity programs, they are only one step in the pathway to a cybersecurity career. Thus, the data collected through the survey of Virginia's STEM-students can be also used to inform best practices and strategies in the K-12 system and after college graduation – in the professional field of cybersecurity, as all of these stages of the cybersecurity pipeline are interconnected and interdependent. In particular, to make a step toward a student-ready cybersecurity program, special attention needs to be paid to: 1) attracting and retaining non-white cybersecurity students; 2) improving the skills of students in the field of business fundamentals; 3) enhancing the quality and the access to advising prior to and in college; 4) removing barriers to graduation and transferring to a four-year institution.

The study that we present in this paper also has various limitations. First, the relatively small sample size which only included four different higher education institutions in Virginia – three community colleges and one 4-year degree granting institution. The experiences of the students in Virginia may differ, and this may result in nuances in the responses to the same question, shaped by internal institution factors. Therefore, a series of interviews and/or focus groups may be further required to gain better insights into the students' experiences. Furthermore, these results should be compared to such from other states as well. Second, while the opinions of minority groups were recorded, as they are particularly important for our analysis, some of them constituted a very small number (1-3 students) of the overall surveyed population and reliable conclusions are difficult to be derived. In addition, some of our results pertaining to female and non-white students may be attributed to the overall higher enrollment of male and white students in the institutions from which our sample came. The same approach – interviews and focus groups – should be applied to understand the experiences in underrepresented groups in STEM and cybersecurity in more detail. The same data collection method should also be used to respond to some supplementary questions that our analysis raised. For instance, whether students do not consider certain university services/resources as important because they do not believe they contribute to their college success in general, or because they had an unpleasant experience with them. Focusing on how to increase participation of female and non-white students in cybersecurity courses, further questions to be asked may involve what services or opportunities that higher education institutions can offer to achieve this result, how the culture in these institutions can change so that they become more welcoming, and what efforts need to be made to ensure a proper transition to them to the job market.

The analysis that we were able to conduct using the data from the survey, except for a few interesting patterns, showed tendencies which are well-described in the literature - in particular, that there were more male cybersecurity students than female. The results also showed that the number of white students is still significantly higher than the number of any other race/ethnicity represented on Virginia campuses, as the number of American Indian/Alaska Native and the Native Hawaiian/Pacific Islander students was minimal. Considering the clearly expressed need for diversity in the field of cybersecurity, there should be conscious efforts to invite, retain and support minority groups to pursue a cybersecurity degree and successfully enter the workforce after graduation. Higher education institutions need to make sure they offer appropriate course delivery methods to their students – in-state, out-of-state, and international. Efforts need to be made to preserving the initial interest of STEM-students in the field of cybersecurity, as the number of those who took between one and five cybersecurity courses in college drastically drops when compared to the number of students who took more than six cybersecurity courses. This anomaly could also be attributed to the overall number of cybersecurity courses offered per institution. To help address this issue, future research needs to focus on how to retain these students in the cybersecurity field, including how to provide the necessary courses to them and how they can quickly and easily transfer to an institution that offers more cybersecurity courses.

One intriguing finding that our study offered pertains to the level of confidence STEM-students have in different cybersecurity-skill areas. While more than 90% of them feel prepared for teamwork, planning and organizing, creative thinking, problem-solving and decision-making, only 68% of them feel prepared when it comes to business fundamentals. This percentage for women is lower than for men. Only 62% of the surveyed women share that they feel prepared, as opposed to 72% of the male respondents.

When it comes to university services, advising was clearly favored as a resource that was linked to college success. This finding was also consistent across all groups (gender, race/ethnicity, and major), except for one race/ethnicity group, but the number of respondents was too low to successfully derive broader conclusions. As for the other services about which students were consulted, there was some variation across individual groups regarding the importance of select services as related to their college success. For instance, peer-mentoring was much more important to Black/African American students than to other races/ethnicities, faculty-mentoring was more important to Hispanic and Multiracial students and to online students, compared to on-campus students, tutoring was more important to Black/African American and Hispanic students than to students from other races/ethnicities. Lastly, while most of the STEM-students who were surveyed expect to graduate from their current institution, some share that it is unlikely for them to do so and mention some of the obstacles standing in the way of their success. They can be categorized conceptually as financial-barriers, time-barriers, and effectiveness-of-learning barriers. It needs to be noted though that these groups are related and a successful strategy to help students on the pathway to a fulfilling cybersecurity career needs to consider each of them, individually, and all of them, as a complex of factors. The student-ready cybersecurity program will only be as successful as each of its students.

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