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BOARD # 67: Environmental Factors Impacting Cybersecurity Students' Major-specific Conceptual Learning

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Environmental Factors Impacting Cybersecurity Students' Major-Specific Conceptual Learning

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Abstract. In this research, the aim is to investigate environmental factors impacting cybersecurity students' learning of cybersecurity major related concepts. The research is conducted in one of the public universities in the Northeastern region of the United States to obtain the results presented in this work. IRB approval is attained to conduct the research. Qualitative and quantitative data is collected from cybersecurity students; The quantitative data is the numerical data attained from 103 students with the aim of determining the environmental factors impacting cybersecurity students' learning in an online course and the factors in their lives impacting their learning in cybersecurity. The qualitative data is collected from students in the form of voice recording during the interviews and the data is transcribed for further processing. Quantitative data is collected by using data distributions, correlation heat maps, ANOVA, and Kruskal-Wallis and Mann-Whitney tests. Overall results indicated the level of engagement in the course to be the highest impacting factor of cybersecurity students' learning while family and work are determined to be significantly important factors for learners while online learning environment and interactions are also important. As for the external factors that impact learning, the work option was determined to be the most popular response as a part of the external factors impacting students' learning.

1. Introduction.

Cybersecurity has grown rapidly over the last decade in response to the increasing sophistication of cyber threats and the growing need for skilled professionals to address these challenges [6,7]. In response, universities have stepped up their cybersecurity programs to prepare students for this technical and analytical field. Although technical skills remain fundamental to cybersecurity education, it is now well appreciated that external and environmental factors have a significant impact on students' learning achievement processes [8]. These factors – personal devices, course organization, professor engagement, work, family, and social life, among others – often determine how well students grasp major-specific concepts.

The major impact of Covid 19 on learning was shifting from in-person to digitized learning. A simple example of this impact is switching from traditional to online learning during the COVID-19 pandemic as well as the accelerated major changes in the cybersecurity profession that impacted engaging with students during lecture coverages [12]. This change played a significant role in the university students' learning and the environment that they were learning. There is a broad range

of environmental factors that include but are not limited to personal devices such as cell phones, computers etc. as well as physical environmental factors such as work, family, sports friends etc. that may impact learners' education. The research on environmental factors impacting cybersecurity students' learning has been focusing on applications of cybersecurity in different environments instead of the environmental factors impacting students' learning. For instance, students are observed to be motivated to practice information security if they perceive high levels of severity, response efficacy, response costs and self-efficacy in cyberspace [1]. Psychological factors impacting pedagogy of cybersecurity education is discussed in [2] with its impact on students' learning. Exploration of influencing factors in cybersecurity major or career choices is limited and most of the literature focuses on correlation of personality traits, academic performance in traditional STEM subjects such as math and science, and environmental factors such as parents, teachers, counselors, and socio-economic influences [3]. Students having little to no exposure to cybersecurity education within traditional middle school and high school curriculum and environments is pointed out as one of the environmental factors in K12 education [4]. Understanding environmental factors that impact university-level cybersecurity education and investing in fixing relevant issues that exist to apply corrective actions may play a significant role in the future of not only cybersecurity professional environment but also students' choices of cybersecurity education. Despite recent improvements in cybersecurity education, most research has focused on technical skills and awareness of risks such as gamification-based learning [9], self-regulated learning strategies [10], and the psychological aspects of pedagogy [11] that have been utilized as different approaches to learning in cybersecurity; However, there remains a gap in knowledge about the broader environmental factors that affect academic success of cybersecurity students. This research is designed to fill this gap by exploring the environmental factors that affect the learning of major-specific concepts in cybersecurity students.

By analyzing the data collected for this study, the research aims to establish patterns that can help improve educational practices and course design in cybersecurity. Recognizing environmental influences on students' education is particularly important given the fast-paced and demanding nature of the cybersecurity field. The findings of this research will provide valuable insights for students, educators, administrators, and policymakers to develop strategies for organizing and delivering more effective cybersecurity education. As students, the demand for cybersecurity professionals keeps growing, these factors will become crucial in getting students ready to address industry challenges [14]. Furthermore, this study contributes to the discussion on how to improve educational practices in technical fields by stressing the role of environmental factors in learning outcomes. It shows the importance of students' lived experiences in addition to quantitative data in creating a more inclusive and adaptable educational framework. In doing so, the research presents an environmental factor perspective on the learning of cybersecurity students as well as opening possibilities for innovative strategies to enhance their academic and professional readiness.

We start by covering research methodology of the study in the next section. The third section focuses on the quantitative analysis of the data. Section 4 contains the qualitative results heavily

relying on the video recorded interviews. The last part of our work focuses on the conclusions and possible future work that can be undertaken by other educators and researchers.

2. Research Methodology

This study was conducted at a public university in the Northeastern United States by a Principal Investigator (P.I.) and a team of five research assistants. The research was approved by the Institutional Review Board (IRB) to ensure that human rights and ethics are applied properly. A survey and follow-up interviews were conducted with the participants' consent collected at each stage of the data collection. The participants were students in the cybersecurity programs; thus, the study was directed towards their experiences and opinions. The data is collected from 103 students and designed to address two research questions:

1. What environmental factors motivate or discourage cybersecurity students' enjoyment and engagement in online courses?
2. What external influences limit students' ability to learn from their cybersecurity courses?

The survey responses provided quantitative results to identify patterns and trends in the data. This was useful as it allowed the research team to identify factors that are most likely to affect student experiences and learning. In addition to the survey, in-depth interviews were conducted to help understand the answers provided by the students in the survey. The interviews lasted anywhere between 30 to 40 minutes, and the students were compensated money for their time and participation. These conversations gave the participants the opportunity to explain in their own words how different environmental factors, such as personal obligations, course features, and the level of support they receive, affect their learning. The interviews were recorded and transcribed to ensure that the data collected was accurate. The following questions are the main drivers of the quantitative analysis provided in this work:

1. What environmental factors impact (i.e. motivate or discourage) you to enjoy (i.e. like or dislike) an online course? Please mark the factors below that you believe impact you.

- My computer
- My cell phone
- Professor
- The educational environment
- Level of engagement in course
- The organization of the course
- Amount of feedback/support from professor
- Amount of course work

2. Which of the following impacts your learning from courses you completed? Please mark the factors below that you believe impact you.

- Family
- Work
- Partner
- Friends

- Sports
- Games
- Social life (such as parties, hanging out with friends etc.)

We continue with the presentation of the quantitative results in the next section.

3. Quantitative Results

The factors that impact students' ability to learn cybersecurity concepts will be analyzed quantitatively by using the survey data. The analysis instruments of the data included the following:

- Distribution of the data points
- Heat maps of the correlation values between the factors selected by the participants
- Mean and standard deviation of the correlation values
- Summary statistics
- Kruskal-Wallis and Mann-Whitney tests

These results will be forming the quantitative analysis of the survey data and the associated summary graphs will be presented. The two parts of the survey instruments stated below will be evaluated independently with the similarity analysis conducted by using the Kruskal-Wallis and Mann-Whitney tests.

Part A. What environmental factors impact (i.e. motivate or discourage) you to enjoy (i.e. like or dislike) an online course? Please mark the factors below that you believe impact you.

1. My computer
2. My cell phone
3. Professor
4. The educational environment
5. Level of engagement in course
6. The organization of the course
7. Amount of feedback/support from professor
8. Amount of course work

Part B. Which of the following impacts your learning from courses you completed? Please mark the factors below that you believe impact you.

1. Family
2. Work
3. Partner
4. Friends
5. Sports
6. Games
7. Social life (such as parties, hanging out with friends etc.)

3.1 Data Distributions & Statistical Analysis

Our main goal in this section is to provide a distribution of the data for each one of the two parts of the data set assuming each part's entire data. Hence, the eight options (with the outlier option eliminated due to low number of responses) of Part A add up to 100% and similar for the 7 options listed for Part B. The associated mathematical distributions are formed naturally, and these distributions will also be stated and interpreted.

It is essential to study the factors that impact online learning to be able to improve learners' comprehension of the concepts of the material and educators to focus on the associated content. A multitude of factors may exist, and this section of the research is focused on the analysis of such factors based on the collected survey data; Figure 1 below demonstrates such factors in percentages with their significance in the entire data set collected for Part A. A linear regression fits the data and forms a triangulation of the data at an accuracy of about 95.8% [5]. This result indicates that all factors change from top to bottom on the graph in a linearly order (in percentage values) with the lowest impacting factor being cell phone with 8.86% as the participants' choice while highest impacting factor was determined to be the level of engagement in the course at a rate of 16.14%. Hence, cell phone factor has the lowest impact while level of engagement has the highest impact as a part of online learning according to learners in this research.

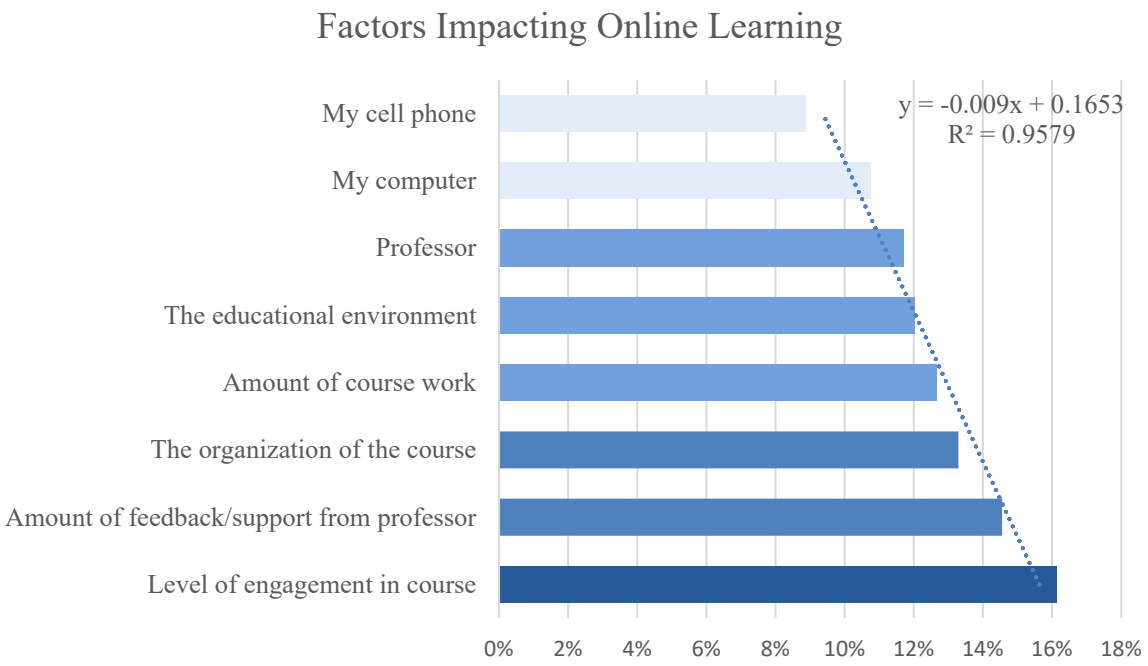

Fig. 1 Distribution of the factors that impact online learning of cybersecurity students.

Similar to Part A's data distribution, Part B's data distribution displayed in Figure 2 also has a strong linear model fit with an R-square value of 98.06% that also allows the formation of the triangulation as explained above [5]. The sports response attained the lowest percentage share within the data set at a rate of 5.56% while the work option gained the highest rate of 22.73% popularity among the responses. Hence, cybersecurity students' work has a major role in their learning while sports category has the least significant impact among all options.

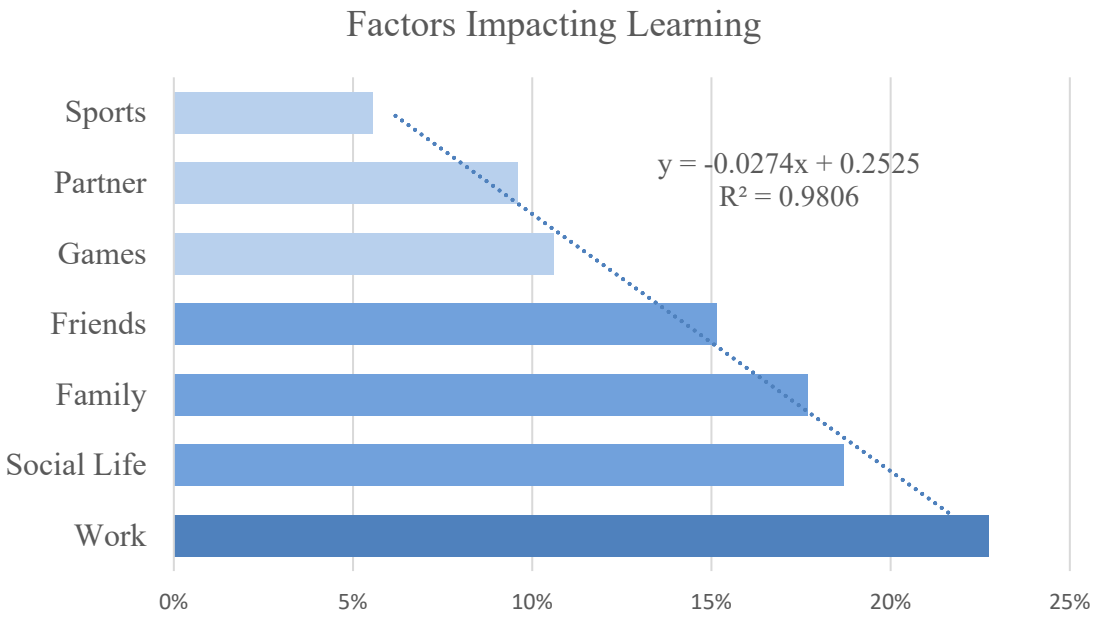

Fig. 2 Distribution of the factors impacting cybersecurity students' learning.

Overall, data of both parts A and B has a linear regression fit with the triangulation's formation for both data sets. Next section covers correlation of the options chosen by the participants.

3.2 Correlation

Correlation has a significant importance for identifying the comprehensiveness of multiple selections of the research participants. Table 1 below shows a comprehensive overview of the percentage of overlapping responses as the correlation of each person's multiple choices, and this table is designed as a correlation heat map for Part A responses. Each percentage value is calculated in this table relative to the overlapping number of occurrences within the respective column category for identifying the matching responses; For instance, there were 22 selections of "My cell phone" that matched with "My computer" category among the 34 selections of "My computer" that resulted in 64.71% correlation between "My computer" and "My cell phone" relative to the number of "My computer" column. This answer is changed to 78.75% in "My cell phone" column noting that the 22 of "My computer" and "My cell phone" choices overlapped among 28 "My cell phone choices".

To analyze the overall results shared in Table 1, starting from the top row with "My cell phone", the heat map indicates a non-steady increase in percentages from top row "My cell phone" to bottom row "Level of Engagement" of the table. It is easy to see that "Level of engagement in the course" option had the most significant overlap with the other choices indicating that majority of the participants selected this option as one of their two options. Similarly, the least popular option was the use of the cell phone as it has the lowest percentages within the associated top row values relative to the other rows of the table.

	My computer	My cell phone	Professor	The educational environment	Level of engagement in course	The organization of the course	Amount of feedback/support from professor	Amount of course work
My cell phone	64.71%		48.65%	42.11%	39.22%	35.71%	32.61%	37.50%
My computer		78.57%	64.86%	60.53%	47.06%	50.00%	39.13%	55.00%
Professor	70.59%	64.29%		52.63%	52.94%	54.76%	58.70%	65.00%
The educational environment	67.65%	57.14%	54.05%		68.63%	66.67%	63.04%	67.50%
The organization of the course	61.76%	53.57%	62.16%	73.68%	68.63%		73.91%	67.50%
Amount of course work	64.71%	53.57%	70.27%	71.05%	74.51%	64.29%	71.74%	
Amount of feedback/support from professor	52.94%	53.57%	72.97%	76.32%	72.55%	80.95%		82.50%
Level of engagement in course	70.59%	71.43%	72.97%	92.11%		83.33%	80.43%	95.00%

Table 1. Relative correlation of options in Part A of the research.

Table 2 demonstrates the summary statistics of Table 1 column values. This table indicates the lowest deviation to be 6.12% from the standard (i.e. average) value of 64.71% attained for "My computer" option. The maximum deviation, 18.45%, from the average, 67.14%, is attained for the "Amount of coursework" column indicating that the choices made for this option had the highest gap among the other options.

	My computer	My cell phone	Professor	The educational environment	Level of engagement in course	The organization of the course	Amount of feedback/support from professor	Amount of course work
Average	64.71%	61.73%	63.71%	66.92%	60.50%	62.24%	59.94%	67.14%
Standard Deviation	6.12%	10.04%	9.47%	16.56%	13.93%	16.97%	18.01%	18.45%

Table 2. Summary statistics of Table 1.

Table 3, just like the design of Table 1, reflects Part B of the research correlation values. Given the focus on factors such as work, family, friends, social life, partner, games, and sports, the columns display the participants' overlapping choices in percentages. For instance, 100% of the participants that picked sports also picked work as an option while only 24.44% of the participants who picked work also picked sports as an option. The lowest correlation, 10.81%, occurred within the social life category due to the limited selection of sports choices within this category. Analyzing the overall table row by row, it is easy to see a decreasing pattern in percentages on most of the rows from top row to bottom. For each option (i.e. column), the sports option received the lowest percentage of correlation that turned out to be less than 27%; therefore, sports option is not a commonly selected second option within each category except work, family, and friends.

	Family	Work	Partner	Friends	Sports	Games	Social Life
Work	80%		78.95%	80%	100%	80.95%	78.38%
Family		62.22%	68.42%	63.33%	81.82%	52.38%	67.57%
Friends	54.29%	53.33%	78.95%		63.64%	61.90%	62.16%
Social Life	71.43%	64.44%	57.89%	76.67%	36.36%	71.43%	
Partner	37.14%	33.33%		50%	45.45%	33.33%	29.73%
Games	31.43%	37.78%	36.84%	43.33%	45.45%		40.54%
Sports	25.71%	24.44%	26.32%	23.33%		23.81%	10.81%

Table 3. Relative correlation of options in Part B of the research.

Table 4, just like Table 2, demonstrates the summary statistics of Table 3 column values. This table indicates that the least deviation from the standard (i.e. average) is attained for the work option, therefore this option had the lowest deviation, 16.43%, from the average value of 45.93% among the options. The maximum deviation of 25.61% from the average value of 48.2% is attained in this table for the social life column indicating that the choices made for this option had the highest gap among the other options.

	Family	Work	Partner	Friends	Sports	Games	Social Life
Average	50.00%	45.93%	57.89%	56.11%	62.12%	53.97%	48.20%
Standard Deviation	22.26%	16.43%	22.08%	21.54%	24.67%	22.06%	25.61%

Table 4. Summary statistics of correlation values displayed in Table 3.

3.3 Mann-Whitney U and Kruskal-Wallis H Tests

We use the Mann-Whitney U and Kruskal-Wallis Tests for identification of the relationship between Parts A and B. Mann-Whitney U test is applied to Parts A and B data as two independent groups and the results indicated statistically significant outcomes to favor the null hypothesis that also confirms the statistical significance of the two distributions similarity attained in Subsection 3.1. Considering each response to Parts A and B as a group within the 15 selections of the participants, the application of the Kruskal-Wallis H test resulted in a p-value of 17.62% (that is also reflecting the Chi-square distribution value) to conclude the level of significance for the collected data's distribution to be about 17.62%.

4. Qualitative Results

Qualitative results we present in this work have high importance in understanding the details of the quantitative responses of the participants. Given the large quantity of the collected data, we only demonstrate samples of some of the popular answers and some of the students' justifications of their quantitative choices.

Qualitative data is collected during a 30-40-minute video recorded interview of the participants as a follow-up of the survey responses to better understand their responses, and these results are transcribed for understanding details of research participants' justifications. Participants are compensated for participating in a 30–40-minute video recorded interview that served as a follow up interview to better understand survey responses. The P.I. conducted the video recorded interviews with the participants while research assistants worked with the P.I. on the survey data collection from the students. A comprehensive analysis and overview of the integrated qualitative and quantitative responses will be presented in the last section of the article. Several examples of qualitative data will be demonstrated in this section for both Parts A and B.

The factors that impact cybersecurity students' learning both online and in-class directly relate to life-related conditions. Covid 19 had a big impact on traditional learning and the mind-set of learning changed to online learning for some students while it remained to be as in-class learning for some students. Each person's additional real-life experiential learning experience are reflected in the person's responses. For instance, the following participant chooses to learn in an online environment; Family and learning environment are the two major factors that impact both participants' responses.

Interviewer*. What environmental factors impact you to enjoy an online course?*
RP 1. *Definitely the educational environment is the most important part of it.*
Being able to do it from home is critical. The feedback and support from the professor are important, so I know I'm on track. Computer or cell phones? Not really relevant, and the level of engagement is good. You know when there's a lot of like open discussion and. Input from classmates and questions from the professor that usually keeps me really engaged.

Interviewer. *Which of the following impacts your learning from courses you completed?*

RP 1. *I am married, I have a daughter, I have a home I have to take care of. So those are priorities that can take my attention and sometimes difficult to find time to do the homework.*

Participant 2 prioritizes the interaction with professor and amount of coursework as the primary choices for Part A while family and friends are favored by this participant for Part B.

Interviewer. *What environmental factors impact you to enjoy an online course?*

RP 2. *I would probably put communication with the professor #1. Amount of coursework #2. Amount of feedback and support from Professor next. The educational environment #4. Level of engagement 5. 6th Organization of the course. And then seven computer 8 cell phone… I would say I don't mind doing discussion boards and assignments and stuff like that, but if on top of that you're asking me to do a lab*

every week and on top of that, a quiz, you know, it can be huge. If it's like that it can be a lot. If it wasn't for that much work, I would definitely have liked the course a lot. I'm in the belief that if you give too much work to a student, it doesn't increase engagement and learning it kinda decreases it. I feel like you can only learn so much from doing assignments. You do learn, but if you give them too much, you can get them to generally dislike the material and not wanna put their best effort every time to do the assignments because it's just too much work. I think it'd be a lot. So, it is fair to say, for example, there's a threshold value that you can't really predetermine, but you have that gut feeling and sense to actually understand when too much is too much and that simply triggers for you to not like or dislike. I can't determine cause I'm sure it's different from everybody and how much work is too much work I unknown. I think the amount of work you gave the student kind of defeats the purpose. And now it's like he just wants to, you know, finish the course and not have to take his time or really digest the material. He's just looking to get the class grade, the passing grade and move on. So I feel like giving out too much work online and in person is just too much. It really does deter the student from really engaging from the class cause. Now the class becomes more of a chore and busy work than it is about just learning the material so, you know, I think that stops students from learning.

Interviewer. *Which of the following impacts your learning from courses you completed?*

RP 2 *OK, I would say work, friends, family, social life. Yeah, I would just leave those for.*
I feel like all these things are just enough because my job isn't directly in cybersecurity so it just deter you from actually learning, because it just takes up time from learning.
So I'm sure it can have positive impact, but for me like generally these things like just take up time and don't really like give you the chance to like maybe take a class that you might have otherwise taken because of time constraints or just you know stop you from actually focusing on the material at home and stuff like that, you know... For me, the professor is the number one factor. If the professor is engaging and really connects with the class, it makes me want to show up for the online sessions. When they're asking questions, explaining things thoroughly, and keeping the class interactive, it's so much more enjoyable. That kind of teaching makes me feel like I'm part of the learning process, and it motivates me to stay involved. On the other hand, the structure of the course also matters. Online classes can sometimes feel less productive compared to in-person ones, but if the professor is engaging, it balances things out. It's easier to stay focused and feel like I'm learning something valuable. So yeah, having a professor who's engaging and passionate really makes me love attending online classes—it's the biggest factor for me.

Interviewer. *Which of the following impacts your learning from courses you completed?*

RP 2 *Sure. I'd say family is number one. Family is so important because when you're dealing with family issues or struggles, it can really distract you from learning. But when you have a supportive family, it makes a huge difference. They're there to help, especially parents—they always want you to succeed. They're the ones who say this is what life is about, and they guide you through tough times. Having that connection and support from family really keeps me grounded and focused. Friends would be number two. If you have good friends on campus who are in the same major, like cybersecurity, they can be a big help. For example, if your friends have already taken a class, you're in, they might say, here's what to expect, or this is what worked for me. They help you navigate the courses, share tips, and even motivate*

you to stay on track. So yeah, for me, it's family first and then friends. Both are really key to staying motivated and successful in my career.

5. Conclusions & Future Works

Factors impacting cybersecurity students' online learning and overall learning experience are researched in this study. In this IRB approved study, quantitative and qualitative data is collected from 103 students in a cybersecurity program of a university located on the northeastern side of the United States. The quantitative data is formed by the survey responses while the qualitative data is formed by the interview responses of the participants to a 30-40 video recorded interview. The video recordings are transcribed for furthermore qualitative analysis. The qualitative and quantitative analysis of the data are integrated in this section to draw conclusions and provide a comprehensive overview of the results to the following two parts of the survey:

Part A. What environmental factors impact (i.e. motivate or discourage) you to enjoy (i.e. like or dislike) an online course? Please mark the factors below that you believe impact you.

9. My computer
10. My cell phone
11. Professor
12. The educational environment
13. Level of engagement in course
14. The organization of the course
15. Amount of feedback/support from professor
16. Amount of course work

Part B. Which of the following impacts your learning from courses you completed? Please mark the factors below that you believe impact you.

8. Family
9. Work
10. Partner
11. Friends
12. Sports
13. Games
14. Social life (such as parties, hanging out with friends etc.)

The responses to Part A displayed in Figure 3 below indicated the major interest of the participants in online learning to be level of engagement in the course that directly relates to human factor aspect of the course. The qualitative responses furthermore indicated this component to be considered as interaction with the professor, classmates, learning management system, and amount of coursework. The correlation between all these components has a high-level importance in the learning process given that the interactions between the learner and the learning environment could have the highest impact that starts with the organization of the course and progresses with the engagement in the course. The amount of coursework can encourage or discourage the level of interest in the course.

Figure 4 displays the factors impacting the students' learning from a variety of perspectives that are external to the student's learning environment. The major factor is determined to be work that also highly correlates with family for the students that work with a family to support. In correlation with these factors, social life becomes a major factor in relation to these two factors.

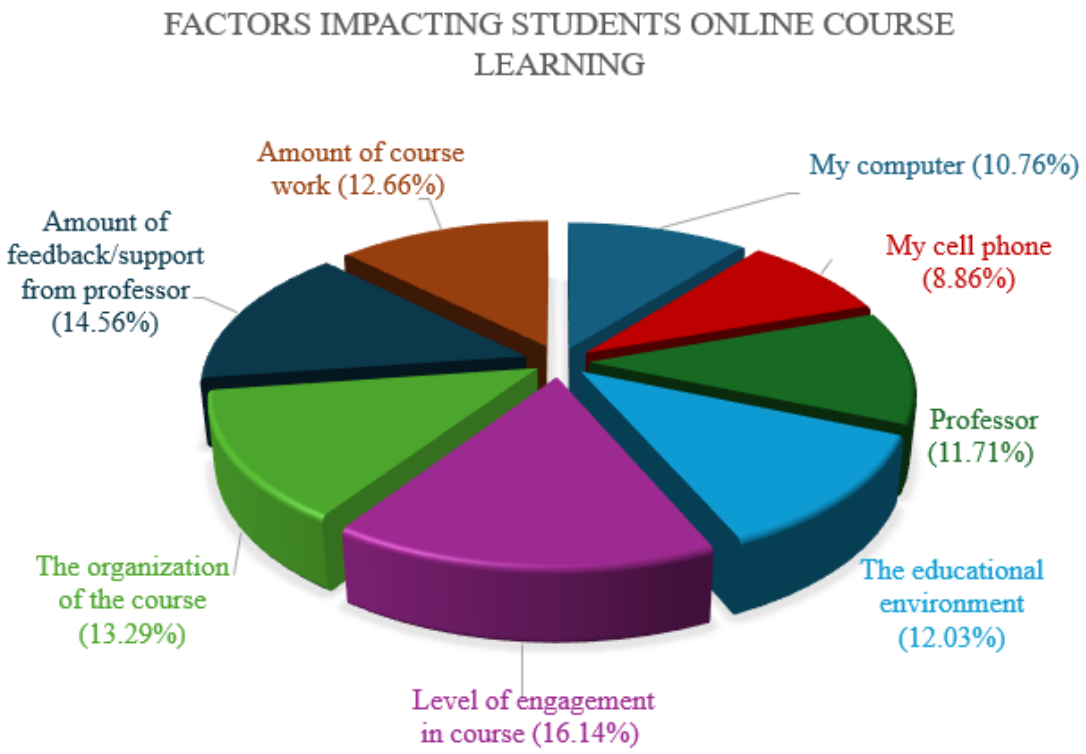

Fig. 3 A summary of the factors impacting cybersecurity students' learning in an online course.

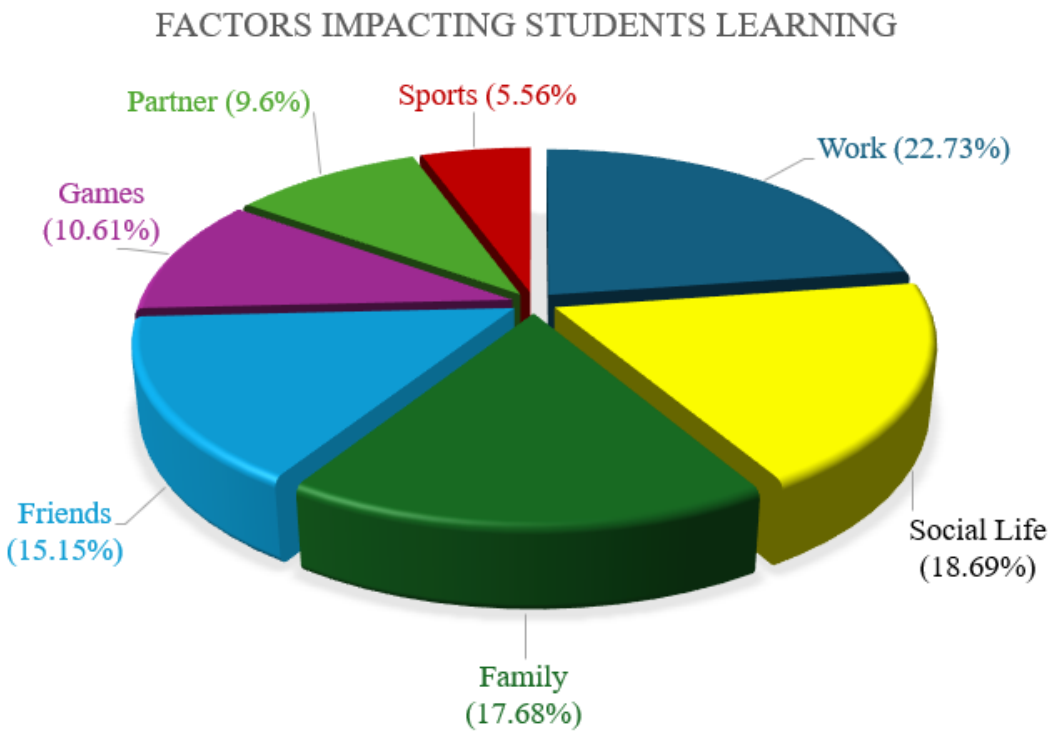

Fig. 4 A summary of external factors impacting cybersecurity students' learning.

Integrated qualitative and quantitative analysis of the data result in the following key takeaways:

- *Part A responses.* Cell phone option has the lowest impact on students' learning in an online course that was favored at a rate of 8.86% of the research participants while the highest impacting factor is determined to be the level of engagement in the course at a rate of 16.14%. From a correlation perspective, level of engagement in the course option had the most significant overlap with the other choices indicating that majority of the participants selected this option as one of their two options. Similarly, the least popular option was the use of the cell phone. This option was also reflected in the qualitative responses in a way that cell phone was not mentioned as one of the major factors in online learning. Family and work are significantly important for learners while online learning environment and interactions are also important.
- *Part B responses.* The sports response attained the lowest percentage of external factors that impact learning within the data set at a rate of 5.56% while the work option gained 22.73% popularity among the responses as a part of the external factors impacting learning. Hence, cybersecurity students who work have a major role in their course learning while sports category has the least significant impact among all options. From a correlation perspective among the choices picked by the participants, 100% of the participants who picked sports also picked work as an option while only 24.44% of the participants that chose work also chose sports as an option. The lowest correlation of 10.81% occurred for the social life category with sports due to the limited selection of sports choice within this category.

We invite other researchers and educators to invest in similar pedagogical research for understanding the factors that impact cybersecurity students learning; This is directly correlated with the pedagogical needs and how educational settings can be improved for further advancing the cybersecurity educational program environments. Noting that there is a tremendous increase in the number of educational programs and professional opportunities in the cybersecurity field, understanding and improving educational needs of learners through investments in this kind of research is essential to not only improve student education but also professor's understanding levels of such factors and establishing empathy with the students.

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