Integrating Pedagogical Frameworks and Critical Theory in Cybersecurity Education Research: A Holistic Approach

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ABSTRACT

The NSF's Secure and Trustworthy Cyberspace (SaTC) education directive emphasizes evidence-based practices to promote a robust, diverse, and inclusive cybersecurity workforce. This study aligns with this directive by exploring equity issues in online/hybrid cybersecurity learning environments. Guided by pedagogical frameworks and critical theory, this study focused on cybersecurity students, particularly individuals with multiple marginalized identities, self-reported classroom experiences. Findings highlighted the perceived benefit of inclusive practices, such as group assignments and interactions with knowledgeable figures of similar identities. This study underscores the importance of investigating cybersecurity education praxis and learner experiences jointly to create supportive and equitable learning environments.

CCS Concepts

• Applied Computing • Education • Distance Learning • E-Learning

Keywords

postsecondary education; online pedagogy; broadening participation in computing; community of inquiry; quantcrit; critical theories; mixed-method design

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1 Introduction

The presented research was part of a larger study [1] examining the pedagogical practices undergraduate cybersecurity students found beneficial to their cybersecurity learning. The education and learning science frameworks of the Community of Inquiry (CoI) [3][4], the Online Pedagogy Framework, the Interactive, Constructive, Active, Passive (ICAP) framework [5], and standards from Quality Matters [6] guided praxis components of the initial study due to higher education's shift and acceptance of the online modality [7], as well as understanding the role Active Learning has in cybersecurity education. A contribution of the initial study was incorporating a critical lens to interrogate the NSF's Secure and Trustworthy Cyberspace (SaTC) [2] Broadening Participation in Computing (BPC) initiative, specifically in how Critical Race Theory (CRT) in education [8][9] and Intersectionality [10][11] grounded the study, and the application of QuantCrit [12] to the study's design, implementation, analysis, and interpretation of results. This paper, as a segment of the larger study, illustrates scholarly work centering BPC targeted identities of Women, Black/African Americans, Hispanics/Latinx, American Indians, Native Hawaiians, Pacific Islanders, and non-gender conforming persons. Individuals with these identities were intentionally sought to 1) fill a gap in cybersecurity education literature on learner self-reported classroom experiences and 2) interrogate what these learners needed in their cybersecurity learning environment. Hence, the following research questions:

- *Are there differences between perceived online or hybrid cybersecurity course experiences of Broadening Participation in Computing (BPC) identity holders?*
- *How do individuals with gender and race/ethnicity dual membership perceive pedagogical practices and Instructional Supports implemented in their online or hybrid cybersecurity courses?*

2 Theoretical Framework

When critical theories inform education research, they allow an examination of existing and hidden oppressions by guiding the research process from beginning to end. QuantCrit, as a critical theory descended from CRT, informs the actions of a critical quantitative study by identifying systemic barriers in education systems facilitating inequities for groups considered underrepresented. A primary motive for QuantCrit's use in this study is supported by broadening participation calls in the SaTC solicitation, lack of authentic and relevant attention on marginalized cybersecurity student experiences in their cybersecurity learning environments [13][14], and the low presence of critical theory informed cybersecurity education research.

2.1 QuantCrit Tenets

2.1.1 The Centrality of Racism. This tenet acknowledges racism and, by extension, sexism, classism, etc., as being embedded in education structures. This awareness guides critical quantitative researchers to seek understanding through inquiry that answers questions such as why and where inequities in education systems occur and what the effects of education system inequities are on social identity groups. For this study, the centrality of racism, framed within a cybersecurity education context, is a proposition that racism and other biases are present in cybersecurity learning environments in the form of instructional practices meant to foster cybersecurity learning. This study treated the centrality of racism tenet as a generative point of consideration, meaning it served to guide critical awareness in terms of what to look for in marginalized student experiences reported quantitatively and how such experiences connect to cybersecurity education praxis.

2.1.2 Numbers are not Neutral. While statistical analysis techniques for quantitative data are universal, the intention behind their employment requires consideration. Questions such as 'how' or 'what' the data represents is paramount to generating accurate interpretations, where the integration of contextual information is necessary to learn and understand underlining and/or persistent issues. For this study, the numbers are not neutral tenet guided research design methodological decisions, so data from individuals belonging to BPC targeted groups were obtained with respect to the premise that numerical data is not free from bias [12]. Adhering to QuantCrit's second tenet necessitated this study's approach of not limiting nor completely removing identity groups to meet traditional quantitative rigor.

2.1.3 Categories are Neither Natural nor Given: For 'Race' Read 'Racism'. The employment of categories in education research characterizes and classifies the qualities of individuals. From a critical researcher's perspective, it is prudent to question the use of categories formed on socially constructed identities since identities are developed through societal interactions and are based on a myriad of experiences within a cultural context. The second part of the categories are not natural principle, "for race read racism" is a reminder that identity constructs are subjective, created individually, have situational meaning and can fluctuate, which contributes to variability in experiences and perceptions. However, research centering social identities is a prevalent gap in cybersecurity education literature. This study, as a demonstration of critical scholarship, includes identities not explicitly stated in the SaTC's broadening participation designation to cover the diverse array of undergraduate cybersecurity students and limit tendencies toward over-generalizations informed by quantitative data.

2.1.4 Voice and Insight. A central aspect of critical quantitative research is "experiential knowledge," which takes the form of articulated "perspectives and understandings" [12] from research participants and researcher interpretations. To the best of this researcher's knowledge, a cybersecurity education study has yet to be conducted where the voices of individuals have been captured to understand non-outcomes/achievement classroom experiences. Therefore, this study leans into the voice and insight tenet as an avenue toward advancing cybersecurity education praxis via authentic voices. Specifically, by learning from the people the BPC is meant to benefit.

2.1.5 Social Justice/Equity Orientation. The last QuantCrit principle relates to the epistemological position of critical research scholars. QuantCrit supports disrupting research norms that perpetuate assumptions and foster inequities. Studies that employ a social justice perspective do so in many ways, such as having an asset-based approach, ensuring transparency, or questioning "perspectives and assumptions reflected in analysis" of existing research [12]. An essential term in the fifth principle is 'orientation', which is significant to this study by ensuring a clear anti-racist, anti-sexist, anti-classist agenda and an awareness of where implicit/explicit biases exist [12]. This study's attention to the cybersecurity learning environment, particularly the pedagogical practices within the learning environment, is an initial step towards social justice by learning what pedagogically informed practices and instructional supports resonate with marginalized and underrepresented cybersecurity students.

3 Positionality Statement

This positionality statement offers insight into how my social identities influenced this study and my cybersecurity education research agenda. My visible social identities as a middle-aged Black woman and invisible identities as a cybersecurity educator and burgeoning critical scholar have shaped my worldview and self-perception. As a cybersecurity teacher, I am responsible for creating a supportive learning environment for students. My role as a cybersecurity education researcher compels me to share insights from lessons learned in my classrooms and my research on cybersecurity students' learning needs. My identities and subsequent experiences in hostile, welcoming, and indifferent environments have influenced my academic work. These experiences drive my commitment to contribute pedagogically authentic and effective methods to the cybersecurity education research community. I believe in the power of diversity and strive to ensure my actions are equitable and serve the greater good. In this study, this means amplifying the voices of marginalized and underrepresented individuals to guarantee they are included in the discourse on advancing cybersecurity education. Hence, my approach to conducting empirical work revolves around the question, "*Who am I doing this for*?" In short, I do this for people like me. I work for those who have the potential to be skilled and knowledgeable cybersecurity professionals when properly nurtured. I adhere to the discoveries of critical scholars because their efforts and persistence align with my beliefs, and because I see no reason not to follow their established paths. As demonstrated in this study, integrating best research practices and principles of critical frameworks is how I authentically and respectfully serve a diverse array of cybersecurity learners while staying true to myself [15].

4 A QuantCrit Paradigm Research Design

QuantCrit is a critical approach for interrogating big data. However, such a repository on cybersecurity students is unavailable. Nonetheless, QuantCrit guided aspects of this study because it compels a researcher to reframe quantitative data's use, analysis, and interpretation with a critical lens from beginning to end. This study's approach to learning about the experiences and perceptions of those experiences from a diverse cybersecurity student population through quantitative data required centering their missing voices while accounting for conflicting and contributing facets of a socially constructed identity.

4.1 Study Design

This study employed a mixed-method approach, where data was collected from a researcher-created cross-sectional online survey capturing cybersecurity students' course perceptions and the classroom practices (i.e., Instructional Supports) experienced. Research incorporating cross-sectional surveys has advantages [16], though challenges with surveys of this type are that they only capture "single point in time" [17] reactions, which limits identifying cause-and-effect patterns [18]. Additional challenges with cross-sectional surveys center on the sample frame, such as ensuring a sample is representative and issues with respondents' satisficing [19]. However, for the research objective of this study, a single point-in-time measurement was appropriate as it afforded opportunities to collect information over the Internet from a broad scope of individuals who were already savvy with digital technologies and were experts in their individual cybersecurity learning experiences. Aside from traditional survey limitations, cross-sectional designs require considerable attention to sample size and inclusion criteria for meeting representativeness and generalizability [17]. However, when a targeted population, such as undergraduate marginalized and underrepresented cybersecurity student makeup is not well known, traditional statistical procedures associated with probability or quota sampling are impractical. In these instances, quantitative studies incorporate alternative methods, such as nonprobability sampling, to compensate. Although nonprobability sampling is a non-traditional practice in quantitative research, its implementation in this study aligned with its QuantCrit paradigm. Specifically, as a counter to quantitative methods that inadvertently or intentionally mask, ignore, or make assumptions regarding marginalized and underrepresented identity holder experiences due to small sample sizes.

4.2 Sample Frame and Population

Adhering to the strict assumptions required for probability sampling was considered unfeasible and out of scope in this study [20][21]. Assuming cybersecurity student data is aggregated with Computer Science or CS-adjacent fields contradicts QuantCrit tenets of critical analysis. Additionally, publicly available datasets describe end populations (i.e., degrees obtained). This study sought degree-seeking cybersecurity students, hence the employment of nonprobability sampling [30] to account for an obscured population. Through purposive sampling, participants were intentionally sought "based on their specialized knowledge of the subject area under investigation" [22] and life experiences. For this study, participants were individuals considered experts due to their first-hand experience in their undergraduate cybersecurity courses, and subsequent perceptions about their learning experiences were considered valuable and trustworthy data sources. Furthermore, purposive sampling acts as a form of social justice in this study. Specific social identities were treated as assets to assuage assumptions that 1) individuals with marginalized or underrepresented identities experiences were unimportant, 2) these individuals did not have cybersecurity learning experiences influenced by their social identity, and 3) current cybersecurity education practices adequately addressed their unique needs [23].

The sample population consisted of undergraduate cybersecurity students experienced with learning cybersecurity in an online or hybrid environment. Study participants were recruited from the cybersecurity student affinity groups Women in Cybersecurity (WiCyS) and the National Cyber Student Association (NCSA). The NCSA, an organization stemming from the NSF-funded CyberWatch program, and WiCyS, a nonprofit organization supporting female cybersecurity students, are student-centered, have postsecondary student chapters across the United States, and provide cybersecurity knowledge and skill development through various opportunities. Student members are vested in becoming cybersecurity professionals, vary in prior knowledge and experience, career intentions, motivations, etc. Although such learner characteristics contribute to the nuanced understanding of cybersecurity students, these aspects were likely captured due to this study's sample frame. While not documented or explored as data points of interest, the variability of such aspects supports the need to prioritize representativeness with respect to context to gain an authentic understanding of cybersecurity classroom experiences. Nonetheless, this assumed variability added value to this study in the form of student reported additional instructional supports experienced and realistic perceptions associated with those experiences.

4.3 Participant Demographics

Recruitment efforts resulted in a small (N = 16) but diverse group. The majority of participants reported an identity of Female, Transgender, Nonbinary, or Agender (FTNbA) (n = 12) at 75%, and (n = 11) 68% of individuals reported a marginalized or underrepresented race/ethnicity. The remaining participants consisted of one male Person of Color (PoC) (6%), (n=2) participants who reported an FTNbA status and non-PoC (13%), and (n=3) respondents reported being male and non-PoC at 19%. Further contributing to the diversity of the sample were participants' classman status, where most (n = 9) were juniors and seniors, and (n = 7) were freshmen and sophomores. The diversity of participant social identities warranted two categorical groups. Individuals identifying as FTNbA and PoC (n = 10) made up the **Intersectioned Identity** group to account for their dual/multiple membership status, and the remaining participants (n = 6) were placed in the **non-Intersectioned Identity** group.

4.4 Study Instrument and Data Collection

To explore undergraduate cybersecurity student experiences in their online/hybrid learning environment, this study employed the researcher-developed Cybersecurity Pedagogical Experience (CPE) survey guided by survey development best practices [24][25][26]. The CPE instrument includes questions from the validated Community of Inquiry (CoI) survey [27][28][29] for its constructs on Teaching Presence (TP), Social Presence (SP), and Cognitive Presence (CP). As theorized in the Community of Inquiry framework, these constructs contribute to a beneficial online or hybrid course experience. They are recognized as necessary in allowing learners to construct knowledge (CP), engage and connect with online/hybrid peers and the instructor authentically (SP), and be afforded opportunities to learn via meaningful activities in a structured learning environment (TP). Although the high-reliability values of CoI constructs have been accepted as closely related and influence each other, a notable criticism of the instrument is its inability to capture the essence of subjective student responses, which challenges uncovering the causes of a beneficial online/hybrid course experience [30]. This study addressed this challenge by collecting responses on pedagogical strategies guided by the ICAP framework's [5] mode of engagement hierarchy and online course management recommendations from Quality Matters [6]. Figure 1 offers a summarized version of the CPE instrument illustrating the relationship between CoI constructs and ICAP/QM-informed strategies.

Community of Inquiry			ICAP/QM	
CoI Construct	**CoI subconstruct**	**CoI Survey Item**	**Mode of Engagement**	**Instructional Support**
Teaching Presence	Design and Organization	• *The instructor clearly communicated important course topics.* • *The instructor clearly communicated important goals.*	**Passive**	• Course Reminders • Instructor Videos • Supplemental Material
Social Presence	Affective Expression	• *Getting to know other course participants gave me a sense of belonging in the course.* • *I was able to form distinct impressions of some course participants.*	**Interactive Constructive Active**	• Built-in Communication • Group Assignments
Cognitive Presence	Triggering Event	• *Problems posed increased my interest in course issues.* • *Course activities piqued my curiosity.*	**Interactive Constructive Active**	• Hands-on Labs • Practice Assignments • Multiple Attempts

Figure 1: CoI, ICAP and QM Mapped Instructional Supports

The CPE survey completed by study participants consisted of 34 Likert CoI questions, a single Check-all-that-applies (CATA) item to indicate specific Instructional Supports experienced during their cybersecurity course, which also allowed respondents to rate (CATA+rating) the practice by level of perceived benefit. The survey also included a single open-ended question, instructing participants to provide an additional practice they found beneficial to their learning and why. CPE demographic questions were presented after CoI, and Instructional Support questions as a best practice [26]. Demographic questions did not ask participants to report specific social identity group memberships (e.g., gender, race/ethnicity). Instead, participants are asked to indicate if they were a member of a marginalized or underrepresented group in yes/no format from a list of broadening participation targeted identities and included an option to decline self-reporting. Although there is a lack of publicly available comprehensive data on undergraduate cybersecurity student makeup, a supposition is that the student population is like the cybersecurity workforce in terms of being predominantly White and male [31]. This assumption is supported by the SaTC solicitation's continued call for marginalized and underrepresented identity participation, which suggests that cybersecurity students with these targeted identities are likely 'one of a few' or 'the only' in their online/hybrid course. Thus, the capturing of identifying information was kept to a minimum to limit undue harm. As such, it restricted analysis of data by social identity subgroups at a micro-level, however, the obtained demographic information disaggregated by macro-level intersectioned identities of gender+ race/ethnicity proved informative.

4.5 Data Analysis

Before CPE survey data was analyzed, a screening process was completed. A challenge with survey research is non-response and satisficing [32]; hence, survey inclusion and exclusion criteria were created to ensure the validity of interpretations and consistency between data units. For this study, a threshold of surveys with 30 (or ≈ 88%) completion for CoI Likert questions was the first retention criterion. Surveys with lower completions were removed from quantitative analyses. However, they were retained if responses to Instructional Support items or the open-ended question were present. Surveys meeting these conditions were evaluated separately. After the initial screening for adequate CoI item completion, responses were reviewed for straight-lining (i.e., little to no deviation between item responses). Any survey meeting this criterion was reviewed against the exclusion criterion of three-minute or less completion time, blank/incomplete CATA+rating items, or blank/non-sensical or repetitive open-ended responses. Surveys failing these conditions were removed entirely. Once the screening process was completed on (N = 31) surveys, (n = 16) surveys were retained, resulting in a response rate of 51%.

4.5.1 Quantitative Analysis Procedures. Exploratory Analysis descriptive statistics of CoI overall and TP, SP, CP construct scores were examined to obtain summary data and identify potential patterns. From this examination, the nonparametric Mann-Whitney U test proved the more appropriate statistical testing method considering the final dataset's small sample size and this study's theoretical framework. Moreover, the skewness of CoI data warranted non-parametric testing as assumptions of parametric tests were not met. A Mann-Whitney U test was performed across the categorical groups' Intersectioned Identity and non-Intersectioned Identity to test for differences in course perceptions (i.e., CoI overall and CoI construct scores). Instructional Support data was limited to examination by frequency table.

4.5.2 Qualitative Analysis Procedures. As noted, this reported study was part of a larger study capturing quantitative and qualitative data from a different and significantly larger sample of cybersecurity students. Due to the number of open-ended responses from that group, their data served as the foundation for qualitative analysis and interpretation of Intersectioned and non-Intersectioned responses.

Open-ended responses from the larger study were analyzed using multiple qualitative practices to contextualize quantitative survey data. Responses were manually reviewed for completion, where missing response items were coded as Did Not Complete (DNC). In Vivo, a First Cycle coding approach provided a sense of the data, promoted participant voice during analysis, and served as a basis for Initial Coding. Although Initial Coding is associated with Grounded Theory, this study aimed to examine participant responses in separate parts to detect and organize similarities and differences. Elements of interest related to terms, phrases, and attitudes towards experienced Instructional Supports. Two rounds of Initial Coding were performed to generate categories of "Positive Benefit," "Intermediate Benefit," and "Negative Benefit" to represent levels of perceived benefit. Two subcategories, "General" and "Specific," were also created to add further context. For example, a response of "*the videos were good*" were coded as "Positive, General", while a response of "*The length of the summary videos was good*" was coded "Positive, Specific" [1]. A Second Cycle coding process of Focused Coding [33] was the final qualitative analysis approach, where contextualized codes representing the data corpus of responses describing student perceptions of benefit (or lack thereof) towards an Instructional Support were developed. The researcher created Focused Codes were organized into two central categories, "Instructional Support Usefulness" and "Instructional Support Experience" and subcategories to further situate the data as shown in Figures 2 and 3.

Focused Category	
Instructional Support Usefulness	Describes perceptions or provides insights toward an Instructional Support
Instructional Support Experience	Describes understanding or knowledge gained from Instructional Support utilization

Figure 2: Focused Code Categories

Instructional Support Usefulness Subcategories		
Evaluation		Assessment of an Instructional Support
Helpfulness		Assessment of an Instructional Supports' contribution
Learning Benefit		Assessment of an Instructional Supports facilitation toward subject matter comprehension
Need		Assessment of an Instructional Supports perceived value and/or necessity
Instructional Support Experience Subcategories		
Group Dynamics	*Whole Group Communication*	References factors and/or interactions related to all members in a course (i.e., students, instruction, or external individuals)
	Peer-to-Peer Communication	References factors and/or interactions related to student members in a course
Relatability and Applicability		References explicit connections and/or relevance of curriculum subject matter
Understanding and Purpose		Indicates a connection or disconnect towards an Instructional Support

Figure 3: Focused Code Subcategories

5 Results

5.1 Quantitative Findings

The categorical groups of Intersectioned Identity and non-Intersectioned Identity were created based on the final dataset. A boundary for the non-Intersectioned identity holder group is that three members reported one marginalized/underrepresented identity. As noted in the literature, individuals with an underrepresented or marginalized identity have unique experiences and can face challenges coloring their experience. For example, being the only Woman in a technology-focused course or limited interactions with other shared identity holders in online environments. Nonetheless, a boon towards authentic interpretation is that ten participants reported multiple marginalized/ underrepresented identities.

5.1.1 Are there differences between perceived online or hybrid cybersecurity course experiences of Broadening Participation in Computing (BPC) identity holders? The descriptive statistics for the Community of Inquiry (CoI Overall) and its three presences (Teaching, Social, and Cognitive) indicated generally positive perceptions. The CoI Overall (N=16, M =4.2, SD=1.02) total course perception of benefit had moderate variability, Teaching Presence (N=16, M=4.2, SD = .86) had less variability among participants' ratings, Social Presence (N=16, M = 4.0, SD = 1.09) had slightly more variability and Cognitive Presence (N=16, M = 4.2, SD = 1.05) had moderate variability. The online/hybrid course perceptions mean scores among participants were negatively skewed for CoI Overall, Social Presence, and Cognitive Presence, suggesting most students perceived these areas as benefiting. The positive skew of Teaching Presence scores on the lower end suggests some participants had poor experiences of teacher-to-student interactions or the perception of physical distance (i.e., teacher availability) was more pronounced. However, CoI construct statistics between Intersectioned (n = 10) and non-Intersectioned (n = 6) identities showed an emerging pattern of differences. As shown in Table 1 CoI presence constructs for the Intersectioned group, perceived their online/hybrid cybersecurity courses as a positive experience and beneficial to their cybersecurity learning. In contrast, there was spread and lower perceptions of benefit occurring in the non-Intersectioned group. This difference proved significant ($p < .05$) with medium to large effect for CoI Overall ($z = -2.860$, $p = .002$), Teaching Presence ($z = -2.128$, $p = .031$), Social Presence ($z = -2.813$, $p = .003$), and Cognitive Presence ($z = -2.449$, $p = .012$) from a Mann-Whitney U test [34].

	N	CoI Overall (M)(SD)	TP (M)(SD)	SP (M)(SD)	CP (M)(SD)
Intersectioned Identity	10	4.4 (.97)	4.4 (.88)	4.4 (.97)	4.5 (1.05)
non-Intersectioned Identity	6	3.7 (.87)	4.0 (.76)	3.3 (.88)	3.7 (.86)

Table 1: Categorical Group CoI Overall and Presence Mean Statistics

5.1.2 How do individuals with gender and race/ethnicity dual membership perceive pedagogical practices and Instructional Supports implemented in their online or hybrid cybersecurity courses? Most participants (87.5% to 93%) reported experiencing multiple Instructional Supports in their cybersecurity courses. However, specifics about an Instructional Support, such as length or availability of lecture videos, frequency, or types of hands-on labs (e.g., cloud-based vs instructor-created) were not collected as part of this study. This information would help account for extraneous variables, however the decision to exclude this data was made to 1) keep the survey size down as a survey research best practice, 2) as an exploratory study, such detail would be difficult to predict, and 3) the eight Instructional Supports being investigated were derived from online pedagogy best practices.

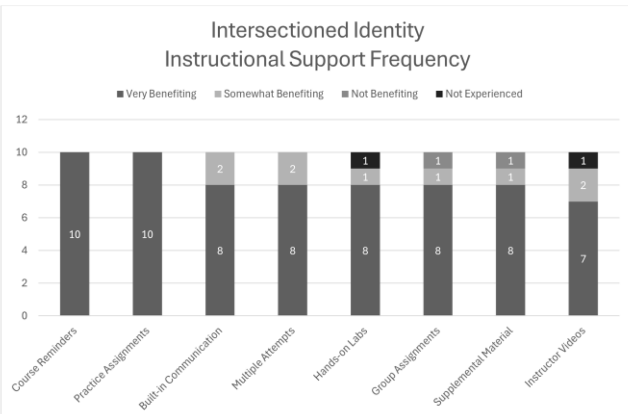

Table 2: Intersectioned Identity Instructional Support Frequency Table

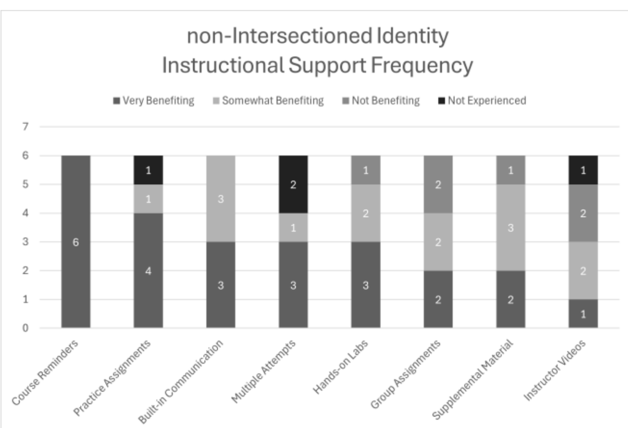

Table 3: non-Intersectioned Identity Instructional Support Frequency Table

The medium to large effect size established from the Mann-Whitney U test for Intersectioned and non-Intersectioned identity holders' course and CoI construct perceptions suggest that students in these categorical groups had different cybersecurity learning experiences. To gain additional understanding, Instructional Supports perceptions were examined to learn what a diverse set of students were experiencing and how or if they contributed to their cybersecurity online/hybrid course experience.

The mean statistics for Teaching Presence, Social Presence, and Cognitive Presence Instructional Supports for the Intersectioned Identity (n=10) were 2.8 (SD = 0.47) for Teaching Presence Instructional Supports, 2.8 (SD = 0.55) for Social Presence Instructional Supports, and 2.9 (SD = 0.31) for Cognitive Presence Instructional Supports. In contrast, the non-Intersectioned Identity (n=6) group had a mean score of 2.5 (SD = 0.71) for Teaching Presence Instructional Supports, 2.0 (SD = 0.77) for Social Presence Instructional Supports, and 2.6 (SD = 0.63) for Cognitive Presence Instructional Supports. As shown in Tables 2 and 3, the Intersectioned Identity group consistently reported higher perceived benefit from the Instructional Supports experienced. The Mann-Whitney U test conducted on Instructional Support perceptions revealed the Social Presence Instructional Support of Group Assignments, was significantly different, but due to the small sample size, this was interpreted as a Type I error. However, a supposition from the CoI Mann-Whitney U test and education and learning science literature is that including multiple pedagogically informed practices is beneficial to learning cybersecurity by a diverse set of individuals.

Instructional Support mean and frequency data provide some understanding, such as how Intersectioned identity members overwhelmingly reported most Instructional Supports as 'Very Benefiting', while non-Intersectioned identity holders were more variable in their ratings. A caution with this interpretation is that three of the six non-Intersectioned identity participants reported a marginalized/underrepresented identity. As noted in critical literature, having a minoritized identity can often create barriers, particularly in postsecondary learning environments, which may be manifesting within the non-Intersectioned identity group data. Nonetheless, an interesting pattern from the quantitative data across both groups was the high ratings for Instructional Supports related to additional learning opportunities and course expectations, suggesting cybersecurity students place importance on supports not explicitly tied to building skills, such as hands-on labs.

5.2 Qualitative Findings

The CPE survey open-ended item asked participants to report practices they found beneficial in their cybersecurity online or hybrid course. Of the 16 participants, four responses to the open-ended survey item were collected. However, a value is that three responses were from individuals with Intersectioned Identities and one person identifying as Female, Transgender, Non-binary, or Agender and non-PoC.

Respondent	Intersectioned Identity	Classman Status	Focused Code
1	Yes	Senior	**Group Dynamics** *(Whole Group Communication)*
2	No	Junior	**Group Dynamics** *(Whole Group Communication)*
3	Yes	Sophomore	**Group Dynamics** *(Whole Group Communication)* **Relatability and Applicability**
4	Yes	Sophomore	**Need**

Table 5: Qualitative Respondent Demographics and Focused Code Responses

The a priori focused codes derived from [1] were applied deductively to respondent open-ended responses., where the codes of **Group Dynamics** (*Whole Group Communication*), **Relatability and Applicability**, and **Need** were the most appropriate fit. A notable pattern from the responses is how three of the four respondents remark on positive interactions with the course instructor or external knowledgeable individuals.

"*Having office hours and some female cyber [professional] speakers come in*" (Respondent 1)

"*Opportunity to meet 1 on 1 with Professor*" (Respondent 2)

"*I thought that bringing in speakers relevant to the material discussed in class was super beneficial. It allowed me to see why we were learning what we were learning and helped me understand the purpose of my knowledge in the field. It also made me more comfortable to reach out for positions and learn more from people*" (Respondent 3)

The attention to guest speakers by respondents 1 and 3 expose facets related to identities, however, in different ways. For respondent 1, "female cyber [professionals]" seems to speak to one side of this person's socially constructed identity. The lack of race or ethnicity mentioned in the response raises questions about the benefit of full identity representation, and the value from opportunities to see and interact with someone with the same social identity within online/hybrid learning environments. Respondent 3 notes that just the presence of speakers was a benefit. However, their remark seems more related to developing a cybersecurity identity, particularly since this person was a sophomore. The salient point from Respondent 3 contributing to this idea of a cybersecurity identity is how their remarks speak to instilling the confidence to explore cybersecurity as a potential approach towards improving persistence and retention in the early phases of a cybersecurity student's academic journey. Of the open-ended responses, comments from Respondent 4 hold acute value because they introduce new perspectives to consider.

"*Time flexibility and lowering cost of studies. By getting online course my test out license for a year has covered [multiple] courses, 90% of them. As a low income student that is very beneficial. Also, I don't have to spend on transportation and that's another plus. Also, I can study at my own pace. Having two kids and two jobs I am [able] to manage my time and I'm able to comply with my cyber courses on time due to the fact that I don't have to be in a class at a certain time during the day.*" (Respondent 4)

Cybersecurity, often touted as a field for improving one's life, seems subject to the same trend of higher education's demographic shifts from the traditional secondary to post-secondary immediate transitioning student. Respondent 4 may be such a student based on their myriad life responsibilities. These external aspects of their identity intermingle with their cybersecurity learning experience and lend towards a shift in considering BPC efforts beyond social identities related to gender, race/ethnicity, or disability status. When Respondent 4 talks about the online/hybrid environment's feasibility as an instructional modality, it reinforces the idea that instructional supports have a dual role. The components of an online/hybrid learning environment should foster cybersecurity learning but also allow this learning to occur and be maintained when external factors can pose undue barriers and threats to persistence and retention. Additionally, Respondent 4 and perhaps others with similar circumstances may view supports intended to foster learning or a sense of belonging in an online course as low priority compared to the efficiency of completing a cybersecurity degree program and/or the need for non-curricular supports when an individual has strong internal motivation and adequate independent learning skills.

5.3 Summary and Limitations

The quantitative and qualitative data from this study offer evidence and potential patterns for understanding the experiences of cybersecurity students. Statistical results in this study are not considered conclusive evidence due to the small sample size. However, this study's quantitative data is important in how it illustrates the need to explore cybersecurity classroom experiences by identities since the data indicates patterns of differences.

A noteworthy aspect was the significant differences with moderate effect of CoI Overall and CoI Presence between Intersectioned and non-Intersectioned Identity holders. This contrast in course perceptions, supported by Instructional Support rating data and partially inferred from the qualitative data, illustrates that students with dual gender and race/ethnicity underrepresented and marginalized identities reported better cybersecurity learning experiences. However, the context for how an experienced practice contributed to an Intersectioned Identity holder's perception is somewhat ambiguous without additional qualitative responses. Alternatively, a critical theory and literature-informed supposition regarding non-Intersectioned Identity holders is that having at least one underrepresented/marginalized identity presents unique challenges, which are likely reflected in the spread of their Instructional Support ratings.

Threats to internal validity are considered the main limitations of this study since participants were recruited from targeted cybersecurity student affinity groups and the disproportional categorical group sizes. However, this was expected and accepted due to this study's lens and position as critical scholarly work. Additionally, the aggregated gender identity categorical groups, although created as a survey best practice towards inclusivity, as well as the combination of race/ethnicity categories, 1) contradict the purpose of QuantCrit's categories are neither natural nor given tenant, and 2) limits the interpretation of experiences by individual social identity group. Nonetheless, keeping this data was a social justice orientation stance to counteract notions that limited social identity data is inconsequential. Likewise, a limitation with the qualitative data is how the format of the open-ended survey item challenged the ability to make more than inferences regarding perceptions of reported Instructional Supports. Even so, threats to validity were controlled when possible, such as employing survey design best practices, providing reasonable and balanced incentives for study participation, and utilizing appropriate quantitative and qualitative analysis procedures based on the data collected and this study's theoretical framework.

6 Discussion and Recommendations

6.1 Mixed-Method Research Design

Mixed-method research design is a promising approach for advancing the cybersecurity education domain. Cybersecurity education is shifting from an outcomes and achievement perspectives as primary factors in determining the efficacy of pedagogical strategies to an expanded perspective of pedagogy where cybersecurity teaching, learning, and students are all explored holistically [36][37]. To fully address cybersecurity learner needs, there must be an understanding of those needs, and there is no better way of obtaining this information than from cybersecurity students themselves. Gaining more context, such as prior cybersecurity experience, level of comfort with an online course, or reasons why a classroom practice was beneficial are the types of questions that can inform pedagogical decisions and practices. Though such questions may not influence cybersecurity curriculum, they can impact the efficacy of learning opportunities and non-curricular supports to meet cybersecurity student needs better.

6.2 Trustworthy BPCy

Trustworthy and meaningful Broadening Participation in Cybersecurity (BPCy) can be achieved when guided by critical theories such as QuantCrit to uncover implicitly hidden identities within BPC calls, or CRT in education, which emphasizes Culturally Responsive Pedagogy (CRP) [38][39]. Exploring acts of persistence and resistance marginalized identity holders employ can also uncover inequities [40][41][42], particularly when embedded in qualitative designs. A missing piece of the cybersecurity education puzzle is scholarly work centering, detailing, and interpreting marginalized/underrepresented cybersecurity student experiences. For instance, employing CRP, where students' cultural backgrounds and experiences are assets and when fostered in the classroom, can contribute to a sense of belonging. However, incorporating culturally responsive, identity-conscious practices into instructional practices, curriculum design, and assessment is challenging for cybersecurity education. This is partly due to the breadth and complexity of cybersecurity topics and because the discipline is inherently competency-based. Moreover, considering the current political dismantling of diversity, equity, and inclusion (DEI) efforts [43], it is likely swaying any hesitancy toward investigating socially just and equitable practices [44] will be difficult. Nevertheless, as stewards of building a robust cybersecurity workforce, the cybersecurity education community can meet this challenge. For instance, in the context of the cybersecurity learning environment, critical frameworks specific to cybersecurity learner identities should be integrated, such as Intersectionality for Women of Color, LatCrit for Latinx students, DisCrit for individuals with disabilities, or QueerCrit for persons with nonconforming gender identities. Critical frameworks embedded into cybersecurity education research with intention is how BPCy efforts can be authentically informed and fashioned into sustainable, inclusive cybersecurity education praxis for its diverse array of cybersecurity students.

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References

[1] Thomas, C. (2024). Cybersecurity education praxis and broadening participation in cybersecurity: Pieces of the same puzzle. Electronic Theses and Dissertations. Paper 4302. https://doi.org/10.18297/eld/4302
[2] National Science Foundation (NSF). (2021). Secure and trustworthy cyberspace (SaTC). (Program Solicitation NSF 22-517). https://www.nsf.gov/pubs/2022/nsf22517/nsf22517.htm
[3] Garrison, D.R., Cleveland-Innes, M., & Fung, T.S. (2010). Exploring causal relationships among teaching, cognitive, and social presence: Student perceptions of the community of inquiry framework. Internet and Higher Education, 13(1-2), 31-36
[4] Steele, J., Holbeck, R., & Mandernach, J. (2019). Defining effective online pedagogy. Journal of Instructional Research, 8(2), 5-8
[5] Chi, M.T.H. & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. Educational Psychologies, 49(4), 219-243. doi: 10.1080/00461520.2014.965823
[6] Quality Matters (QM). (2018). Higher Education Rubric Workbook: Standards for Course Design, 6th edition.
[7] Seaman, J.E., & Seaman, J. (2022). Turning point for digital curricula: Educational resources in u.s. higher education. 2022. Bay View Analytics. https://www.bayviewanalytics.com/reports/turningpointdigitalcurricula.pdf
[8] Ladson-Billings, G., & Tate, W.F. (1995). Toward a critical race theory of education. Teachers College Record, 97(1), 47-68. https://doi.org/10.117/016146819509700104
[9] Ladson-Billings, G. (1998). Just what is critical race theory and what's it doing in a nice field in education? International Journal of Qualitative Studies in Education, 11(1), 7-24. doi:10.1080/095183998236863
[10] Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. The University of Chicago Legal Forum, 140, 139-167

[11] Cho, S., Williams-Crenshaw, K., & McCall., L. (2013). Toward a field of intersectionality studies: Theory, applications, and praxis. Signs, 38(4), 785-810.

[12] Castillo, W. & Gillborn, D. (2022). How to "QuantCrit": Practices and questions for education data researchers and users. [EdWorkingPaper: 22-546]. Annenberg Institute at Brown University. https://doi.org/10.26300/v5kh-dd65

[13] Suryotrisongko, H., & Musashi, Y. (2019). Review of cybersecurity research topics, taxonomy and challenges: Interdisciplinary perspective. 2019 IEEE 12th Conference on Service-Oriented Computing and Applications (SOCA), p. 162-167. doi: 10.1109/SOCA.2019.00031

[14] Svabensky, V., Vykopal, J., & Celeda, P. (2020). What are cybersecurity education papers about? A systematic literature review of SIGSCE and ITiCSE conferences. In the 51st ACM Technical Symposium on Computer Science Education (SIGSCE '20), March 11-14, 2020, Portland, OR, USA. 1-7. https://doi.org/10.1145/3328778.3366816

[15] Holmes, AGD. (2020). Researcher positionality – A consideration of its influence and place in qualitative research – A new researcher guide. International Journal of Education, 8(4), 1-10. https://doi.org/10.34293/education.v8i4.3232

[16] Wang, X. & Chenk, Z. (2020). Cross-sectional studies: Strengths, weaknesses and recommendations. Chest Journal, 158(1S), s65-s70. https://doi.org/10.1016/j.chest.2020.03.012

[17] Ary, D., Jacobs, L.C. & Sorensen, C.K. (2010). Introduction to research in Education. Cengage Learning

[18] Shek, D. & Liang, R.L. (2018). Longitudinal data analysis. In Bruce B. Frey (Ed.), The SAGE Encyclopedia of Educational Research, Measurement and Evaluation (pp. 1000-1002). SAGE Publications, Inc. https://dx.doi.org/10.4135/9781506326139

[19] Cummings, C.L. (2018). Cross-sectional design. In Mike Allen (Ed), The SAGE Encyclopedia of Communication Research Methods. (pp. 315-317). SAGE Publications, Inc. https://dx.doi.org/10/4134/9781483381411

[20] Dutwin, D. and Buskirk, T.D. (2017). Apples to Oranges or Gala versus Golden Delicious?: Comparing Data Quality of Nonprobability Internet Samples to Low Response Rate Probability Samples. Public Opinion Quarterly, 81(S1):213–239.

[21] Grant, J. S., & Davis, L. L. (1997). Selection and use of content experts for instrument development. Research in nursing & health, 20(3), 269–274. https://doi.org/10.1002/(sici)1098-240x(199706)20:3<269::aid-nur9>3.0.co;2-g

[22] Ruel, E., Wagner III, W.E., & Gillespie, B.J. (2016). Survey question construction. In E. Ruel, W.E. Wagner III, & B.J. Gillespie (Eds.), The practice of survey research: Theory and methodology (pp. 44-77)/ SAGE Publication.

[23] Gillborn, D., Warmington, P., & Demack, S. (2018). QuantCrit: Education policy, 'big data' and principles for a critical race theory of statistics. Race Ethnicity and Education, 21(2), 158-179. Doi: 10.1080/13613324.2017.1377412.

[24] Baker, R., Brick, J.M., Bates, N.A., Battaglia, M., Couper, M.P., Dever, J.A., Gile, K.J., & Tourangeau, R. (2013). Summary report of the aapor task force on non-probability sampling. Journal of Survey Statistics and Methodology, 1(2), 90-143. https://doi.org/10.1093/jssam/smt008

[25] Boateng, G.O., Neilands, T.B., Frongillo, E.A., Melgar-Quinonez, H.R., & Young, S.L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. Frontiers in Public Health, 6. doi: 10.3389/fpubh.2018.00149

[26] Dillman, D.A., Smyth, J.D., & Christian, L.M. (2014). Internet, phone, mail, and mixed-mode surveys: The tailored design method. Wiley.

[27] Abbitt, J.T. & Boone, W.J. (2021). Gaining insight from survey data: An analysis of the community of inquiry survey using rasch measurement techniques. Journal of Computing in Higher Education, 33, 367-397. https://doi.org/10.1077/s12528-020-09268-6

[28] Dempsey, P.R. & Zhang, J. (2019). Re-examining the construct validity and causal relationships of teaching, cognitive, and social presence in community of inquiry. Online Learning, 23(1), 62-79. doi: 10/24059/olf.v23i1.1419

[29] Stenbom, S. (2018). A systematic review of the community of inquiry survey. The Internet and Higher Education, 39, 22-32. https://doi.org/10.1016/j.iheduc.2018.06.001

[30] Annand, D. (2019). Limitations of the community of inquiry framework. International Journal of E-Learning & Distance Education, 34(2), 1-15.

[31] Reed, J. & Acosta-Rubio, J. (2018). Innovation through inclusion: The multicultural cybersecurity workforce. [White Paper}. Frost and Sullivan. https://www.isc2.org/-/media/Files/Research/Innovation-Through-Inclusion-Report.ashx

[32] Krosnick, J.A., Narayan, S.S., & Smith, W.R. (1996). Satisficing in surveys: Initial evidence. In M.T. Braverman & J.K. Slater (Eds.), Advances in survey research, 29-44. Jossey-Bass.

[33] Saldana, J. (2013). The coding manual for qualitative researchers (2nd edition). Sage Publications.

[34] Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Erlbaum

[35] Berstein, D.A. (2018). Does active learning work? A good question, but not the right one. Scholarship of Teaching and Learning in Psychology, 4(4), 290-307. http://dx.doi.org/10.1037/stl10000124

[36] Dall'Alba, G., & Bengtsen, S. (2019). Re-imagining active learning: Delving into darkness. Educational Philosophy and Theory, 51(14), 1477-1489. https://doi.org/10.1080/00131857.2018.1561367.

[37] Nieto, S. (2016). Language, culture and teaching: Critical perspectives. Routledge.

[38] Hammand, Z. (2021). Liberatory education: Integrating the science of learning and culturally responsive practice. American Educator, 45(2), 4-11.

[39] Covarrubias, A., Nava, P.E., Lara, A., Burciaga, R., Velez, V.N., & Solorzaon, D.G. (2018). Critical race quantitative intersections: A testimonio analysis. Race Ethnicity and Education, 21(2), 253-273. Doi: 10.1080/13613324.2017.1377412.

[40] McPherson, E. (2014). Informal learning in science, math and engineering majors for african american female undergraduates. Global Education Review, 1(4), 96-113.

[41] Cheuoua-Hubbard, A. (2021). Confronting inequities in computer science education: A case for critical theory. In Proceedings of the 52nd ACM Technical Symposiym on Computer Science Education (SIGCSE '21), March 13-20, 2021, Virtual Event, USA, 425-430. https://doi.org/10.1145/3408877.3432453

[42] Ellis, N.T., & Thorbecke, C. (2024, January 11). DEI efforts are under siege. Here's what experts say is at stake. CNN. https//:www.cnn.com/2024/01/07/us/dei-attacks-experts-warn-of-consequences-reaj/index.html

[43] Sparks, D.M. & Pole, K. (2019). "Do we teach subjects or students?" Analyzing science and mathematics teacher conversations about issues of equity in the classroom. Science Education, 119, 405-416. doi:10.1111/ssm.12361