

The Impact of the National Cyber League NCL on Students Skills in Cybersecurity

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Abstract—Cybersecurity is the top priority for most businesses and government agencies. Teaching students practical cybersecurity is one of the challenges for most academic institutions. Some institutions focus on theory and neglect the practical, which is more appealing to students. Besides, it equips students with the skills the industry needs and reduces the gap between academic institutions and the industry. National Cyber League NCL provides a platform where all students nationwide can join and practice. In the fall of 2023, West Virginia University cybersecurity students joined the NCL competition as part of the course requirements. Participating in team and individual competitions was considered a substitute for the project for the course, which consists of 30% of the total grade. In this paper, we evaluated their background and skills before entering the competition (Who they are?), their experience in the competition, their achievements and skills after completing the competition (what they learned?), and how they evaluate their experience (what they think?). In this paper, we measure their involvement with the competition and how the competition assists them in developing their skills. We rely on their opinion and compare that with their performance according to the report card produced by NCL for every team and each individual. We also found that most students were involved between 10 to 30 hours during the semester with the games. Few students were more than 30 hours during the semester involved with NCL. We found that students were reasonably engaged in the competitions in different areas. Students spent more time in the gymnasium and practice games than in actual competitions. Students achieved an average completion of 35% with 73% average accuracy in the gymnasium, average completion was 19%, and the average accuracy was 76% in the practice game, average completion was 29%, and the average accuracy was 60% in the individual games, and 38% average completion and 39% average accuracy in the team games. Most students believed their skill level had improved by at least one or more. The majority of students were satisfied with their learning experience at NCL.

Index Terms—Cybersecurity, Education, Competition, National Cyber League

I. INTRODUCTION

The US government realized the cyber threats and vulnerabilities with the growth of the internet. In response, developing cybersecurity curricula became a major priority by the US government administration in 2013 [5]. Developing the curricula should include new graduate and undergraduate programs and more courses with skilled-based learning outcomes. In addition, the involvement of more practical skills teaching methodology is more engaging.

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One major challenge in teaching is supporting the curriculum with other tools that help students achieve course learning outcomes. Not only that, finding a tool that equips students with hands-on skills and industrial experience is also challenging. Universities usually focus more on theoretical concepts. However, students need to learn more about practical aspects and relate them to the theoretical background. Cybersecurity is one of the most critical areas in the industry. The industry's need for highly skilled graduates is very significant. Forty-two percent of entry-level technology professionals entered the USA job market through the code BootCamp pathway [6]. Most graduates of coding bootcamps find full-time employment [7]. Seventy-nine of employed BootCamp graduates had an average salary increase of 56% [7].

In the last decade, academic institutions and industry realized the importance of bridging this gap by sponsoring initiatives, boot camps, hackathons, and other similar competitions. These initiatives focus on modern skills (e.g., data science, IT, programming, cybersecurity). According to [2], 36,000 graduated from BootCamp in 2018. Similarly, the market growth of coding BootCamp grew from 2,000 students in 2013 to 23,000 students in 2019 [4]. This is a significant growth compared to 1000 graduates in 2013. These initiatives involve internships, virtual competitions, and team or individual competitions. In addition to the industrial skills and experience they are exposed to, students also develop other soft skills (e.g., teamwork, leadership, time management).

One of these competitions is the National Cybersecurity League NCL. This competition in several areas of cybersecurity targets high school and college students in the United States. At West Virginia University, we offer a cybersecurity program. One of the program's courses is the computer incident response course, which introduces students to computer security and forensics. Recently, the department incorporated the NCL competition with the course. The course syllabus weighs 35% of the total grade as a project. Students' experience with the NCL goes toward the 35% of the grade.

NCL's mission is to prepare the next generation of cybersecurity professionals by providing high school and college students and their coaches an online, safe platform for real-world cybersecurity challenges [1]. The goals were to excite young people to participate and learn. Also, give students easy access to the platform regardless of age, skills, or location. More than 13,000 students of all ages represent over 650 colleges and high schools across the U.S.

The NCL virtual training ground features a competitive process and a supportive community, helping students develop, improve, and validate their cybersecurity skills in eight areas (i.e., Open source intelligence, Log analysis, Network traffic

analysis, Cryptography, Scanning, Forensics, Password cracking, Enumeration and exploitation, Web application security). Students are involved in individual and team challenges. Before starting the competitions, they can practice using the gymnasium and practice games. While practicing and playing real games, they can monitor their progress and accuracy in solving their challenges. Their individual Scouting Reports and team rankings validate students' progress and strengths. The Scouting Report ranks every player in nine categories.

Any academic program or a new experience needs to evaluate its impact on student performance, skill level, or careers (e.g., [8]). This paper investigates students' motives in selecting certain cybersecurity areas to learn. Moreover, have they improved their learning and skills after practicing with NCL? This paper evaluates the impact of this experience on students' skills and learning cybersecurity knowledge through participation in the National Cybersecurity League NCL. In addition, we investigate how students performed individually and with their teams based on data collected from NCL's report cards. Lastly, we investigated students' satisfaction with the learning platform, whether they would recommend it to other students, and whether they suggested any improvement. Our research questions can be summarized as follows:

- RQ1: What areas did students focus on, and why did they select?
- RQ2: Does NCL experience impact students' cybersecurity skills?
- RQ3: How did students perform individually and as a team based on the NCL report cards?
- RQ4: Do students recommend the NCL experience to other students?

This paper is organized as follows: The study design of this work is given in Section II. The results of the data collected and analysis are presented in Section III. Students' actual performance based on the NCL report cards is presented in Section IV. Discussion of the results and students' recommendations and feedback are given in Section V. The study is concluded in Section VI.

II. STUDY DESIGN

For this study, we designed a survey to explore students' experience with the NCL. The survey was submitted to all the course students (43 students) after they completed all games with the NCL. The students were open for three weeks, and the announcement was made to them during the last two weeks of classes between November 27th and December 6th.

The survey contained a brief introduction to the study and its purpose. It also assured participants that the data would be confidential, their identities would not be collected, and their responses would not affect their course grades.

Students' backgrounds were the first to explore (who they are?). The background we were interested in exploring was the educational program they belonged to and their level of experience and skills in cybersecurity. Students from different backgrounds take courses in electrical engineering and biomedical engineering, as well as computer science, engineering, and cybersecurity. Even if they were from a cybersecurity

discipline, their experience and skills in cybersecurity are varied.

We explored how heavily they were involved with the computations. For that, we asked what type of games they participated in (individual or team games) and whether they were gymnasium, practices, or competition games. We also explored the number of hours they spent weekly and in total on the games. Also, we explored the areas of cybersecurity they were involved in and how heavily they were involved. What percentage of involvement did they have in each area? What was the reason behind their selection of the area? In this part, we address the research question (RQ1): What areas did students focus on, and why did they select?

Next, we explored how the NCL impacted their skill level. To achieve this, we asked them how they would evaluate their skills before joining the NCL and how they would evaluate themselves afterward. For the two questions, we used six skill levels: novice, beginner, advanced beginner, intermediate, proficient, and expert. This part helps to address the research question (RQ2): Does NCL experience impact students' cybersecurity skills?

To confirm students' self-evaluation with their actual performance, we needed to check their scorecards provided by the NCL system. The report card contained the points they scored based on completion and accuracy rates. This helps to address the research question (RQ3): How did students perform individually and as a team based on the NCL report cards?

Next, we investigated whether they would promote the NCL and recommend it to themselves and other students. In this part, we address the research question (RQ4): Do students recommend the NCL experience to other students? We asked them what would be the chance to use this again and if they would recommend it to other students. We used the net promoter scale (0 to 10). This scale suggests that from 0 to 6, would not continue using the product (i.e., NCL competition), between 7 and 8 are passive, which may consider using it but will not make an effort to promote it to others, and between 9 to 10 are promoters, meaning that they would encourage others to use the product or the service.

Last, we wanted them to elaborate further on what they liked and disliked most in their experience. We gave them open questions and space to express how they think NCL could be improved.

III. RESULTS AND ANALYSIS

This section presents the results and analysis of the data collected. It starts with the demographics of the students and what programs they belong to. It also analyzes their level of involvement with the competition, how they evaluate their level of involvement on a scale of five, and the number of hours they estimate spending in this competition.

A. Students background

The total number of participants for this survey was twenty-four students (1): 45% students are from Cyber security

What is your major?
24 responses

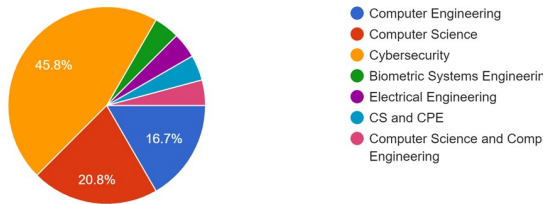


Fig. 1. Students majors

programs, 21% from computer science, 17% Computer engineering, 2% from double major (computer science and engineering), 1% biometric Engineering, and 1% Electrical Engineering. Most students come from cybersecurity programs, and the rest are distributed in different programs connected to cybersecurity (e.g., computer engineering and computer science). Few students are from majors with less connection with cybersecurity (e.g., electrical engineering and biometric engineering).

B. Level of involvement and cybersecurity areas

Participation in the competition was optional. Students were encouraged to participate, and the college department bought all the codes needed. However, if the students choose not to participate in the games, that would be fine, and they can go for an alternative project. For this survey, we only asked students to participate voluntarily if they were involved in any capacity with the competing (as a team or individual games). The majority of students (62%) ranked their participation at the 4th scale (see Figure 2). Other 6 considered their involvement to be on the 5th scale. Also, the total number of hours spent during the semester was investigated. The results is shown in Figure 3, which shows that 8% of students spent more than 30 hours, 33% of students spent between 21 to 30 hours, 42% of students spent between 11 to 20 hours, and 17% of students spent less than 10 hours.

C. Types of games

NCL had four types of games: Gymnasium, Practice, individual, and Team competitions. Most of the students were involved in all types of games. Gymnasium had the highest level of participation (29 students out of 43 students). The reason is that gymnasium games were open from August to December (the whole semester). Other games were opened between 3 to 5 days. All students were involved with the gymnasium and practice games as they were open for a long period. However, we found some students missed individual or team games.

To what extent were you involved with the NCL games?
24 responses

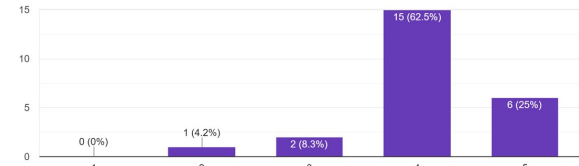


Fig. 2. Level of involvement

In total, how many hours did you spend at NCL during the semester?
24 responses

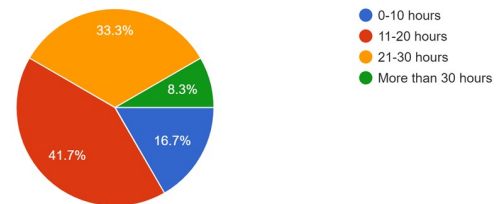


Fig. 3. Total hours during the semester spent on the NCL

D. Cybersecurity areas

Cybersecurity areas were investigated from two angles. First, we wanted to know why they picked certain areas. Was it because they felt comfortable with them and thought they might score high, or did they want to learn new skills to which they had never been exposed? Second, we asked them how heavily they were involved in each area.

The answer to the first question was even; half of the students went for the high score preference, and the other half their motive was to explore new skills, as shown in Figure 4. Certainly, students will still be learning new skills even if they have chosen to score high. Nevertheless, exploring new skills will be more challenging and demonstrate that students prioritize learning rather than earning higher scores.

Figure 5 shows students' level of involvement in each area during the individual or team games. This also answers our first research question **RQ1**. In their competitions or practice, students are more involved in open-source intelligence, password cracking, cryptography, and network traffic analysis. They also chose almost the same areas when they worked as teams. Areas with less involvement were noticed with web exploitation, scanning, and forensics. The motive behind the area selection was divided equally between their need to explore new areas and choosing areas where they felt that the possibility of scoring high was higher.

What was your motivation for selecting the cyber security areas?
24 responses

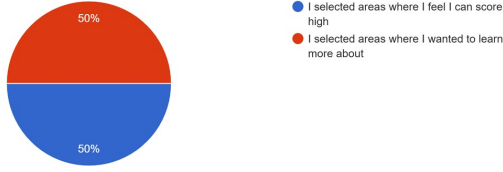


Fig. 4. Students' motive for selecting the area

E. Skills boosters

Did a one-semester challenge boost students' skills? We asked students two questions: how did they evaluate their skill level before and after?

Figure 6 shows the level of students before starting the NCL. As shown in the figure, 33% of students considered their level as a novice, 29% considered themselves as a beginner, 21% put themselves at an advanced beginner level, and 17% considered themselves at an intermediate level. Before the competition, the highest level was upper intermediate, and most fell between novice and beginner levels.

In Figure 7, we found an expansion in the advanced beginner level (from 21% to 29%) and intermediate (from 21% to 46%) levels. Also, we noticed that the percentage of novice students shrank from 33% to 3%.

By comparing the two figures (i.e., Figure 6 and 7), we can infer the answer to the research question **RQ2**. As shown in Figure 6, more novice students (33%) are seen than in Figure 7 after experiencing the NCL. Similarly, more intermediate-level students (46%) are shown in Figure 7 than in Figure 6 before practicing the NCL. This indicates that NCL training and competition significantly impacted students' cybersecurity skills.

F. Students recommending NCL

We used the net promoter scale to see how students stand in recommending the NCL to others. Thirty-three percent of students were on the promoter scale (9 and 10), and 42% were detractors (on a scale of 0 to 6). The promoters are very likely to be reusing the platform again or recommending it to other students, and the rest might not. The answers to what students did not like about NCL might explain the reason. Students elaborated more when they were given a space where they could express their opinions. To answer the research question **RQ4**, students found some limitations they would like to improve to be promoters of the NCL.

IV. STUDENTS PERFORMANCE ON NCL

In this section, we present the performance of our students in the NCL competitions based on the data presented on the NCL coach portal. This is one of the benefits of the NCL.

It allows instructors to have access to all students and see their performance. This helps to encourage them during the semester to do more work on the NCL and improve their accuracy. In our case, we agreed to use their performance on NCL as a project, which is 30% of the total coursework assignments. Furthermore, analyzing their performance in this section with the results of the previous section helps address all research questions.

In the **gymnasium**, we had an average completion of 35% with 73% average accuracy. We had a total of 29 students involved in the gymnasium. Students participated with a minimum of 150 points and a maximum score of 5685 (95% completion). Four students scored between 4,000 and 6,000 points, and six scored between 2,000 and 3,500 points. We spotlight the accuracy of the students who achieved 3,000 points or higher (60% of completion or higher). All of them achieved higher than 65% accuracy. The best accuracy reported by this group was 82%.

In the **practice games**, the average completion was 19%, and the average accuracy was 76%. There is less completion here because the gymnasium was open for an extended period (between August 21 and December 15th). In contrast, the practice game was only available for five days (between October 10th and October 15th). Due to the short period of the practice games, twelve students could participate. The minimum completion rate was 4% (30 points), and the maximum was 48% (830 points). The highest accuracy was 100% (2 students), and a few other students achieved 93%, 88%, and 83%.

The **individual games** was open between October 20th and October 22nd. The average completion was 29%, and the average accuracy was 60%. Twenty-one students participated in the individual games. The highest completion rate was 52%, and the highest accuracy was 76%.

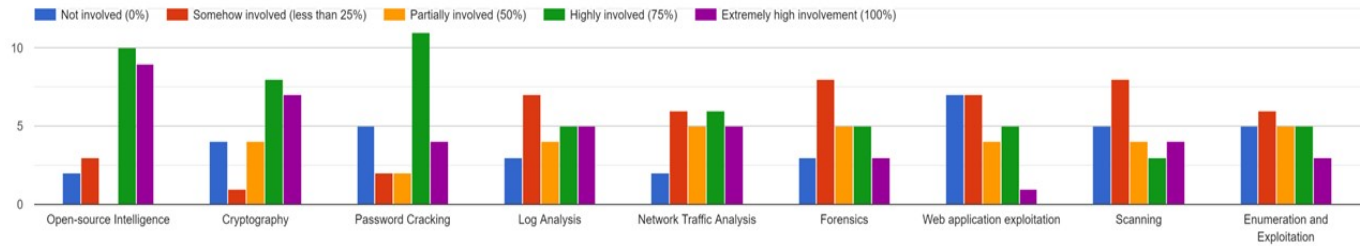
Eleven teams participated in **team games** with 38% average completion and 39% average accuracy. The size of teams varied from two members to six members. The best-performing team completed 54% of the games with 50% accuracy, ranked number 148 nationwide.

To answer the research question **RQ3**, students completed higher averages working as teams. Teams, however, achieved less accuracy. It seemed that when students grouped in teams, they encouraged each other to progress, work harder, and compete with each other and with other teams. Achieving less accuracy as teams could be due to different levels of activities. Another reason is that some strong students might not be involved in team competitions. So, their participation in the individual competition raises the accuracy average.

V. DISCUSSION

In this section, we analyze the significant findings of the survey results and students' actual performance and address the research questions (see Table I). We also highlight the main answers to the survey's open questions (What did they like and dislike most about the NCL experience?). Answers to these open questions identify areas of improvement for the platform, which can be very valuable for the NCL community. Lastly,

To what extent were you involved in the following skills of individual practices and games?



To what extent were you involved in the following skills of the team games?

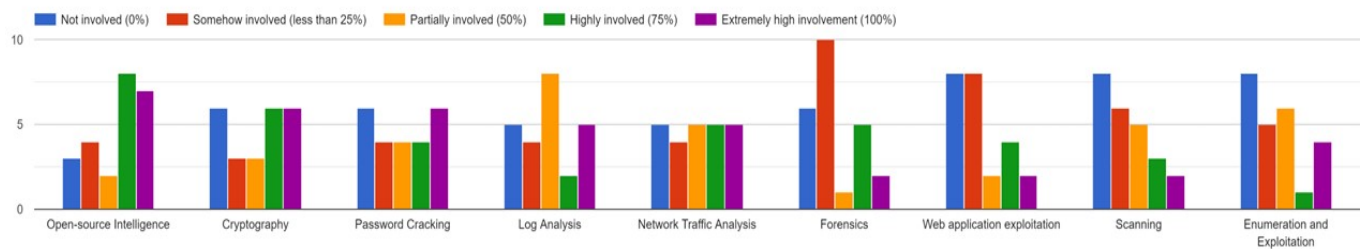


Fig. 5. Students' level of involvement in cybersecurity areas

How do you evaluate your skills in computer forensics before becoming involved in the NCL?
24 responses

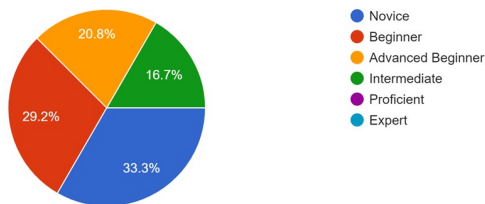


Fig. 6. Students' skills level before NCL

How do you evaluate your skills in computer forensics after becoming involved in the NCL?
24 responses

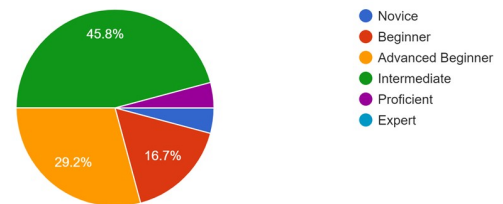


Fig. 7. Students' skills level after NCL

we discuss how the findings of this study can be generalized and the long-term findings on NCL.

This study highlights educational tools for cybersecurity that are integrated into university education course settings. The experience enriched and boosted students' practical skills. By observing students' activities through the report cards and their answers, we found positive feedback on students' engagement and learning by practice. Students found multiple areas to learn

from, and not all of them were covered in a single course of the cybersecurity program. Students could learn through individual practice, games, and team competitions. Students believe that their skill levels improved after completing the NCL challenges.

We found that student's evaluations regarding their involvement with the NCL platform and actual results are consistent with their report cards. Report cards demonstrate the points

In a scale of 0 (no chance) to 10 (highest chance), would you be continuing using this tool or other similar tools to improve your skills.

24 responses

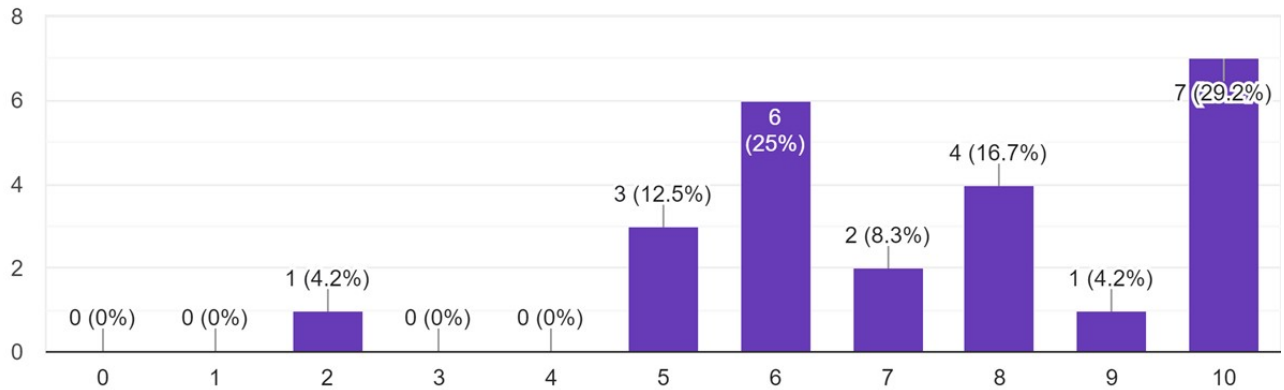


Fig. 8. Students' Net Promoter Score scale of NCL

they scored during practice or competitions and the completion rate, consistent with the hours they said they spent. In addition, the skills they achieved are demonstrated by the accuracy rate they achieved. Students achieved better performance with the practice game and the gymnasium, which indicates the level of difficulty of the actual competition is more challenging than the practice game. Several students also pointed out this when asked to write about what they did not like about the NCL.

Next, we summarize main points of the open questions at the end of the survey (i.e., what they liked and disliked most). These questions help to identify strengths and weaknesses (areas for improvement).

What did you like most about NCL?

When reading all their answers to this open question, we learned several interesting points from students. Some of these points were pointed out through the responses to the survey, and others were pointed out during their final presentation. We summarize and highlight major points. We found several students who liked working on teams and learning from different backgrounds. In addition, they liked the structure of the competition, precisely the diversity of exercises and different levels of challenges within each area. Students liked using real-world tools and when they were exposed to tools for the first time. Some students were particular about identifying tools they enjoyed working with, such as Linux commands, password-cracking tools, and Web Application Exploitation. Some students enjoyed working on the competition and mentioned that it was fun despite the fact they did not get all the solutions correct. They also mentioned that they liked how some helpful materials and videos guided the solutions

and how that helped them learn. Specifically, the gymnasium exercise had detailed explanations to guide them to solutions that helped them understand and improve their skills.

What they did not like about NCL?

Students pointed out several areas of improvement by answering this question. First, they found that different games (i.e., gymnasium, practice, individual, and team games) had different questions. This did not help them prepare for the actual game. For example, they spent time practicing in the gym or playing games, and when they came to the individual or team games, they found different and more challenging questions. We believe bringing similar questions on the practicing games would make students better prepared for the actual games and help them compete better.

Some students recommended having a list of resources to apply for certain skills or questions to practice offline. Other comments concerned the ease of access to the sessions during the game, and they pointed out if the window was adjustable to ease access during the session.

A student noted that some questions were ambiguous and that it was hard to understand the requirements. Another student was frustrated that he was close to the correct answer but scored nothing. The hints given to explain some questions were not very helpful. Other students believed the platform was not beginner-friendly and required some pre-knowledge about the area.

The time designated for the actual games was limited to a few days. Some students believed that more days would have been better. Students pointed out that individual and team games were held on weekends, which was challenging.

TABLE I
RESEARCH QUESTIONS ANSWER SUMMARY

Research Question	Answer
RQ1: What areas did students focus on, and why did they select?	Individual students were highly involved (70% of their time in the platform or higher) with open-source intelligence (19 students), password cracking (15 students), cryptography (13 students), Network Traffic Analysis (11 students), and log analysis (10 students). Teamed students were highly involved (70% of their time in the platform or higher) with open-source intelligence (15 students), cryptography (12 students), password cracking (10 students), Network Traffic Analysis (10 students), log analysis (7 students), and Forensics (7 students). It was found that 50% of students selected the area based on their motivation to explore skills. The other half selected the area based on their confidence in the area and where they believed they would score high.
RQ2: Does NCL experience impact students' cybersecurity skills?	Yes, 50% of students before practicing the NCL are novices or beginners. After the NCL experience, more than 50% are advanced beginners or intermediate.
RQ3: How did students perform individually and as a team based on the NCL report cards?	Individual performance was measured through the gymnasium (73% average accuracy), practice games (76% average accuracy), and individual games (60% average accuracy). The team games measured the team performance (39% average accuracy). There are three types of challenges to compare against the team challenge. However, students believed that gymnasium and practice games were easy and incomparable to individual or team games. As noted, the average accuracy for the gymnasium and practice games is higher than that of other challenges. Individual games had lower competition rates and higher average accuracy than team games.
RQ4: Do students recommend the NCL experience to other students?	Thirty-three percent of students are promoters of the NCL experience. Twenty-five percent of students are passive based on the definition of the net promoter score.

A. Study limitations

This study was conducted for one group from West Virginia University, which took the class on computer incidents in Fall 2023. We cannot generalize the findings of this study on other groups who took the competition earlier from the same university or those who were involved in the competitions from different schools. Therefore, to improve generalizability and reach a solid conclusion on the benefits of NCL education, we should conduct studies in other colleges where students are taking NCL. In addition, a longitudinal survey at West Virginia University, where the same groups can be tested in the future to evaluate the impact on career, similar to the study conducted in [8]. At the same time, new groups from the same university are participating in similar surveys to see if they have similar or different impacts. Also, some controlling factors (e.g., age, gender, or registered programs) should be used to see whether they benefited differently.

VI. CONCLUSION

In conclusion, we found several papers discussing reports that discuss students' participation figures in coding competitions or similar platforms. However, we hardly find studies that evaluated the experience and how it impacts students' skills. In this paper, we highlighted students' participation in the NCL competitions. Students pointed out some significant benefits of participation and some limitations. We measured their involvement in this competition and how it helped them boost their skills. We also used data from the report cards of individuals and, as a team, measured their performance based on completion rate and accuracy. Although students did significantly well, the promoting score could be much higher. We highlighted some of the points mentioned by students, which may be used to improve the platform.

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