Assessment of the Educational Benefits Produced by Peer Learning Activities in Cybersecurity

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Abstract

Peer learning activities may represent a solution to several problems in the cybersecurity education field. Peers have the potential to engage students in was that instructional staff do not. Effective peer learning activities may also aid the scalability of cybersecurity degree programs, which is critical given the shortage of qualified instructional staff and immense need for qualified security professional graduates from degree programs. This paper presents cybersecurity peer learning activities conducted at the North Dakota State University and assesses them using a student survey. It demonstrates the efficacy of these activities for increasing students' technical skills and excitement about the topics of the peer learning activities.

1. Introduction

There is a significant and growing need, both in the United States and around the world, for graduates with strong skills in the area of cybersecurity. These individuals are highly sought after and command some of the highest first post-graduation job salaries. As part of the cybersecurity development efforts at the North Dakota State University (NDSU), a student association was formed for students pursuing coursework in the cybersecurity field. This organization hosts multiple types of activities, including participation in cybersecurity competitions, outreach events and speakers. One of the best received type of events that it hosts is peer learning sessions. Initially, these peer learning events were sporadic; however, in recent semesters they have been more regimented and organized into key categories including red team, blue team and reverse engineering. Some general (non-categorized) ones are occasionally held too.

Students benefit from these activities significantly. Those attending these peer learning sessions benefit from participating in the typically very hands-on activities. However, the students that are, generally, receiving the greatest benefit are those that are organizing the activities, who have to prepare the material to lead the sessions. In additional to learning knowledge and developing skills related to the technical topic, peer learning leaders also develop communications, project and time management skills.

These peer learning activities cover lots of areas, related to cybersecuritym that are not covered by the basic curriculum and cover some areas in a more hands-on way. The activities typically involve the learning leader demonstrating key skills and imparting knowledge, while the learners follow along and try the same tools and techniques that the leader demonstrates. The enthusiasm of the peer learning leaders typically transfers to the peer learning session learners. These learners also typically see the material that is being presented as being within their reach because their peer (who is leading / presenting it) has understood and worked with the material successfully.

This paper presents the results of a survey to characterize the benefits enjoyed by students participating in these peer learning activities. This survey collects demographic information about the student participants, including their role in the peer learning activities. Students were asked about their reason for deciding to participate. They were also asked to indicate what their expectations for participation were and whether each is being met. It also asks the students about their per- and post-participation status with regards to several key areas of potential growth.

In addition to presenting and analyzing the basic results of this survey, the results are analyzed with regards to students' role in the peer learning process and demographic characteristics such as their current academic level and year in their program.

The paper closes with a discussion of the efficacy of peer learning activities for teaching students cybersecurity skills. Prospective areas for future work, including longitudinal tracking of participants and a broader study are also discussed.

2. Background

Cybersecurity is an area where numerous new trained professionals are needed [1], both domestically and internationally. Currently only about 70% of cybersecurity positions are filled in the United States [2], with over 200,000 positions seeking applicants, at present. Cybersecurity, however, is not a single area of focus. It includes a number of sub-disciplines with unique skill requirements. These include malware analysis [3], cryptography [4], steganography [5] and intrusion detection [6], among others.

Due to the need for trained individuals, cybersecurity has been a subject of considerable research on how to best train and educate students. Studies have focused on instructional techniques, including competitions [7], gamification [8] and puzzle-based [9] and challenge-based learning [10]. What topics to cover [11] and how to best instruct students in cybersecurity [12], [13] have also been considered. A number of technologies [14]–[17] and exercises [18]–[21] for lab assignments have also been evaluated.

This paper considers peer instruction [22] and peer mentoring [23] in cybersecurity. Peer education has been seen, since at least the 1980s [24], to provide significant and often untapped educational benefits. It has been shown to both increase students level of achievement and their motivation [25]. Peer learning has been shown to be effective in varied environments including for educator development [26], technology classrooms [27] and online learning environments [28], [29]; however, it has been shown to present assessment challenges [30].

While peer learning can take many forms, in the computational science disciplines and cybersecurity, it often will be conducted in a project- or problem-based learning (PBL) environment. In these environments, students are presented with (or may self-select) a problem or challenge to solve or a project (e.g., software development) to complete. The efficacy of PBL has been demonstrated at multiple levels of education [31]–[36]. It has also been shown to be effective in numerous disciplines. Examples of the effective use of PBL can be found in computer science [37] and electrical [38] engineering. It has also been demonstrate to be effective in non-STEM disciplines such as management [39] and marketing [40]. Further, it has been shown to aid job placement [41] and enhance students' self-image [42] 'soft skills' [43] and creativity [44].

3. Description of Peer Learning Activities

At NDSU, cybersecurity students participate in a number of different types of peer learning activities. These include activities specifically designed to prepare for cybersecurity competitions such as the National Cyber League (NCL) and the Collegiate Cyber Defense Competition (CCDC) regional competition. Students also participate in peer learning activities related to student-driven research projects and identified areas of personal enrichment. Recent topics of peer learning have included red team and blue team competition preparation, fake news identification and reverse engineering.

Peer learning groups have one or more student leaders and choose their own meetings days and times, typically groups meet once per week; however, some have breakout or working meetings. The groups meet occasionally with a faculty advisor or mentor and group leaders have more frequent (typically biweekly) faculty interaction. While in some cases the topics of focus are externally generated (e.g., by competition focus areas), typically the groups are largely self-directed and pick their own areas of focus and pace of work.

4. Student Participants' Demographic Information

Student participants in cybersecurity peer learning activities at NDSU were surveyed about their experience (based on a survey design previously used in [45]–[47]). This section provides some basic demographic information about the student participants and subsequent sections discuss their reasons for participating and the benefits they hoped to and believe they did attain. These results are from a survey administered at the end of a semester of peer learning activities.

Figure 1 depicts the breakdown between undergraduate and graduate students: 78% of respondents were undergraduates and 22% were pursuing masters' degrees. Over half of the undergraduates were senior-level students, as shown in Figure 2, which presents the class-level of the undergraduate student respondents.

Student respondents were also asked to report on their cumulative GPA, which is presented in Figure 3. Note that over half of respondents had a 3.0 or better GPA.

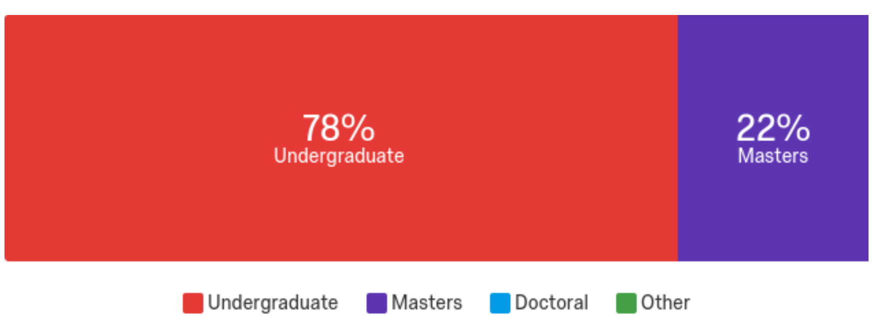

Figure 1. Academic level of participants.

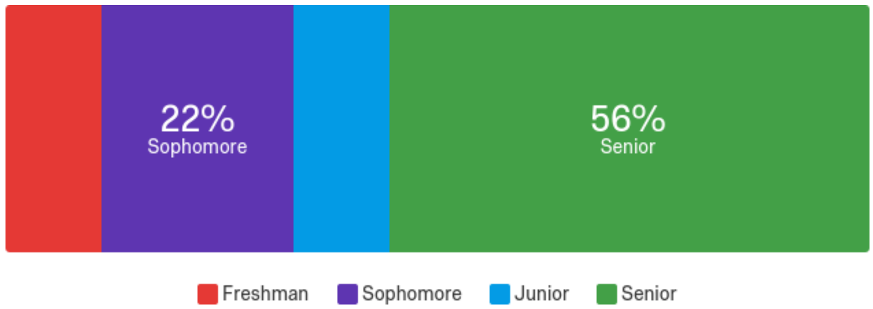

Figure 2. Class level of undergraduate participants.

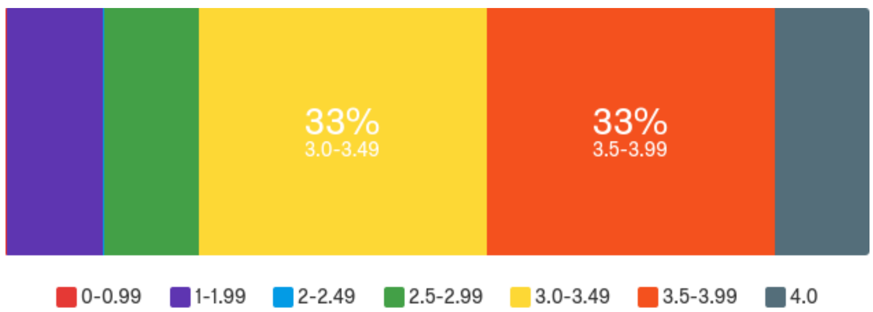

Figure 3. Participants GPA.

5. Details About Respondents' Participation

Student participants were also asked about their participation habits. As shown in Figure 4, most respondents indicated that they attended most (75% or more) sessions. All respondents attended at least 50% of sessions.

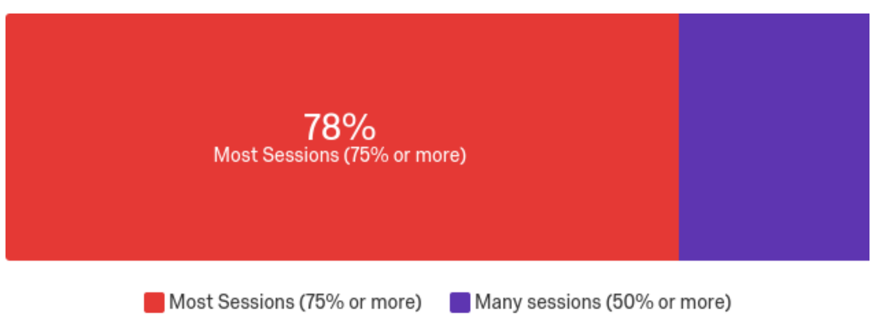

Figure 4. Level of attendance.

Respondents were also asked to indicate their role in the peer learning activities they were participating in. Most indicated, as shown in Figure 5, they were a participant in the activities, while just over 20% indicated that they were a group or team lead. Respondents were also asked to indicate how much time each week they spent on participation. These results are presented in Figure 6. Approximately one-third of respondents indicated spending less than 2 hours per week on their peer learning activity. Another third indicated spending between 2 and 4 hours per week and the remaining third spent between 4 and 10 hours per week on participation.

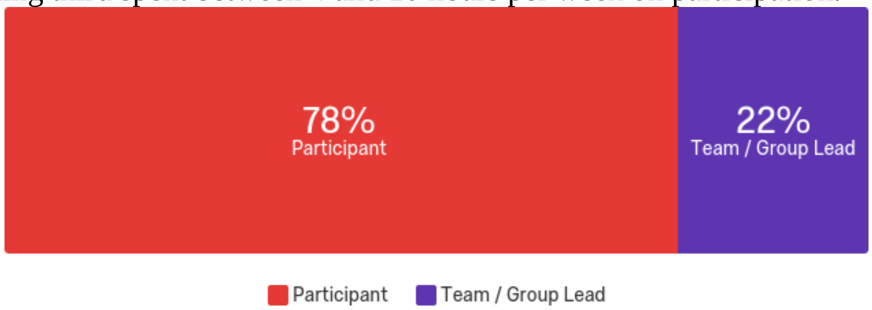

Figure 5. Respondents' role.

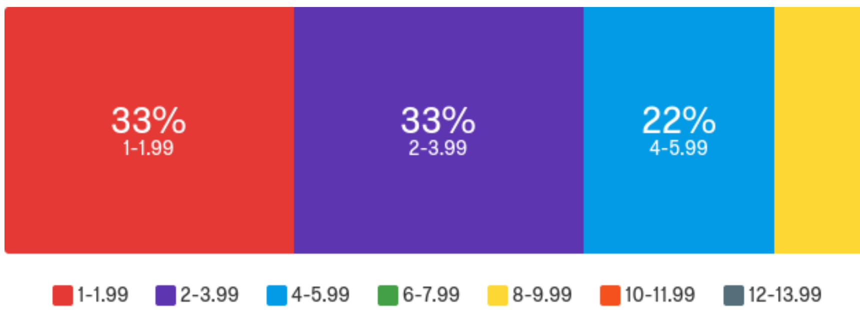

Figure 6. Hours per week of participation.

Respondents were also asked whether they were receiving academic credit for their participation. Most indicated that they were not and were participating solely for personal enrichment purposes. As shown in Figure 7, some were participating for a course project, independent study or other type of credit.

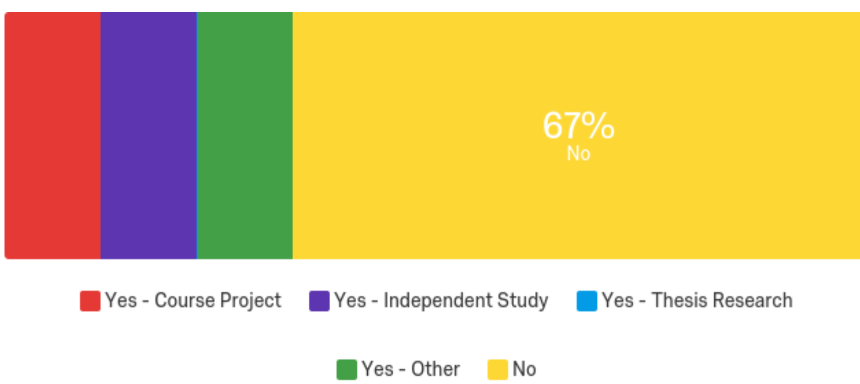

Figure 7. Participants receiving academic credit for participation.

6. Respondents' Reasons for Participation and their Attainment

Respondents were also asked what benefits they hoped to attain and attained through project participation. The benefits sought and attained are presented in Table 1. The most attained benefit was knowledge about a particular technical topic, with 78% of respondents reporting attaining this benefit. Knowledge about the topic of the peer learning activities, improving technical skills and an gaining an item for one's resume were also highly sought (67%). Knowledge about the topic of the peer learning activities and improving technical skills were both attained by the same percentage of respondents as were seeking this benefit. Only 56% of respondents felt that they attained a resume benefit, despite 67% seeking this benefit. Alternately, in a number of areas more individuals reported attaining a benefit than seeking it.

Table 1. Benefits sought and received by student participants.

Benefit	**Sought**	**Attained**
Knowledge about the topic of the peer learning activities	67%	67%
Knowledge about structured design processes	33%	22%
Knowledge about a particular technical topic	67%	78%
Knowledge about project management	33%	22%
Knowledge about time management	33%	33%
Leadership experience	22%	33%
Improving technical skills	67%	67%
Improving time management skills	33%	22%
Experience working with those from other disciplines	33%	33%
Real-world project experience	22%	33%
Item for resume	67%	56%
Improved presentation skills	22%	11%
Inclusion as author on technical paper	33%	22%
Experience working on a large group project	11%	33%
Experience with a structured design process	11%	11%
Experience related to a particular technical topic	44%	33%
Project management experience	22%	11%
Time management experience	33%	22%
Improving leadership skills	22%	22%
Improving project management skills	22%	22%
Understanding of how my discipline relates to others	22%	0%
Learn other discipline's technical details/terminology	22%	11%
Improved chance of being hired in desired field	56%	33%
Increased self-confidence	56%	22%
Ability to present at professional conference	11%	11%
Recognition in the university community	33%	11%

Participants were also asked if they were interested in seeking employment in their field of participation (Figure 8) and whether they felt participation would aid them in attaining employment (Figure 9). Over 75% of respondents indicated interest in employment in the field, with 44% indicating strong interest. Over 75% of respondents also indicated that participation would aid them in attaining employment in this area, with 33% indicating that they strongly believed this.

Finally, respondents were asked about their reasons for participating. Their responses are presented in Table 2. Nearly 90% indicated that the technical topic drove their participation.

Two-thirds indicated excitement about the peer learning topic and a resume benefit drove their decision making.

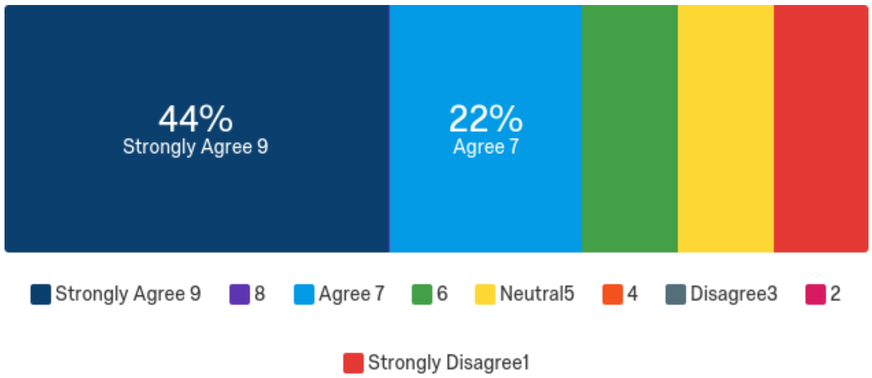

Figure 8. Interest in employment in field of participation.

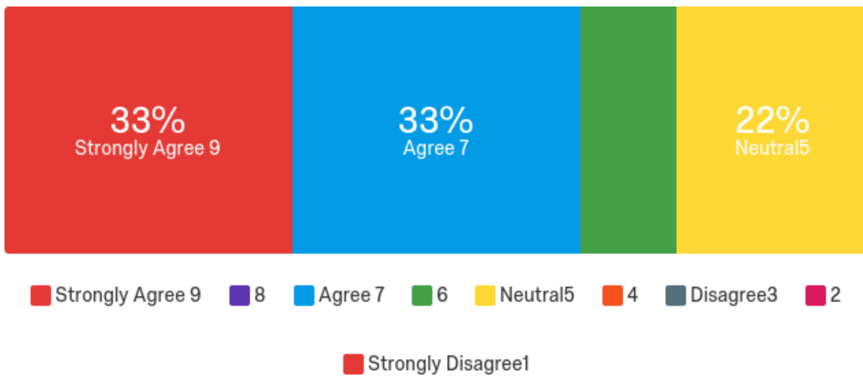

Figure 9. Belief that participation will aid in securing employment.

Table 2. Students reason for participating.

Reason for Participating	
Participation in particular technical area	89%
Excitement about the peer learning topic	67%
Friends are participating	44%
Satisfaction of course requirement	22%
Benefit to resume	67%
Particular faculty member is participating	11%

7. Assessment of Students' Benefit Attained from Participation

The benefits that students attained from participation as well as their attribution of the attainment of this benefit to participation in the peer learning activity was also assessed. Most respondents (60%) indicated not having prior experience in their area of participation, as shown in Figure 10. Respondents were asked to characterize their pre- and post-participation status with regards to several areas.

Figure 11 depicts the gains in technical skill level enjoyed by the participants. Before participation, over 75% of respondents indicated that their skill level was average (5 on a Likert-like scale or below). After participation, over 75% of respondents indicated above average skill level.

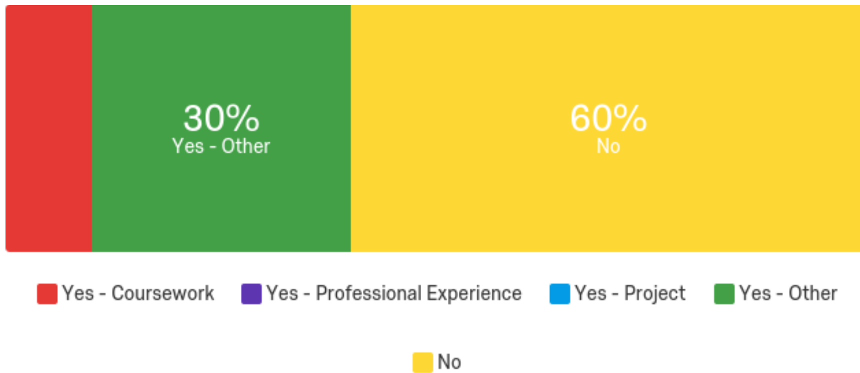

Figure 10. Previous involvement.

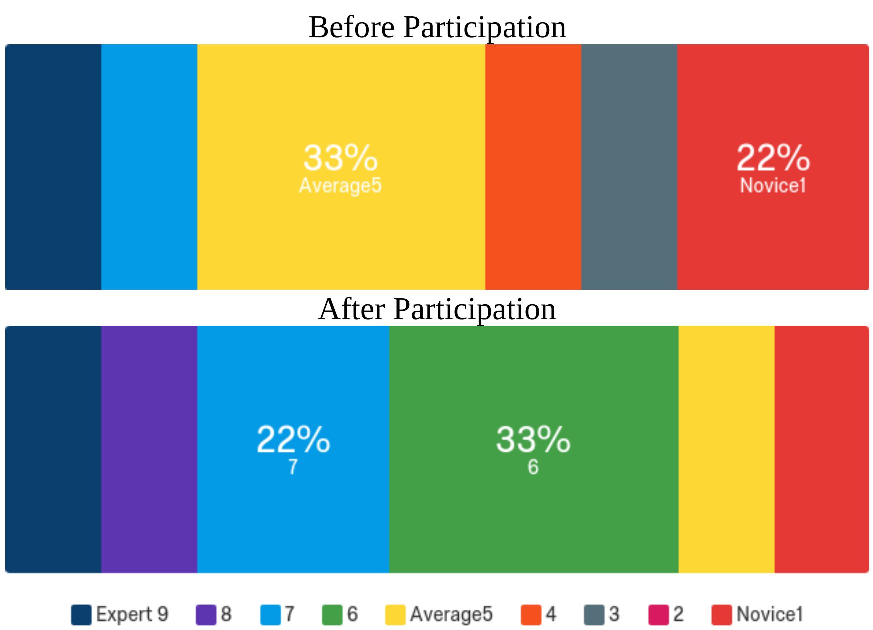

Figure 11. Technical skill level, before (top) and after (bottom) participation.

Respondents were also asked about their level of comfort with the technical area. Their responses to these questions are presented in Figure 12. Before participation, approximately one-third of respondents had below-average comfort, a third had average comfort and a third had above average comfort.

Participants were also asked about their pre- and post-participation level of excitement about their area of participation. These responses are presented in Figure 13. The level of excitement increased significantly. Before participation, about half of participants had above average levels of excitement. After participation, all respondents indicated above average excitement.

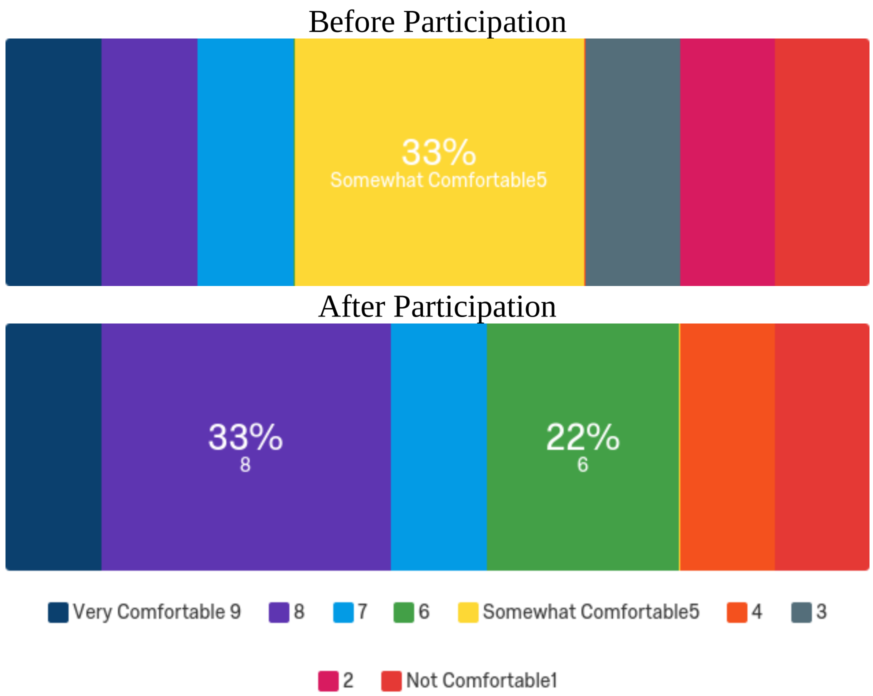

Figure 12. Technical comfort, before (top) and after (bottom) participation.

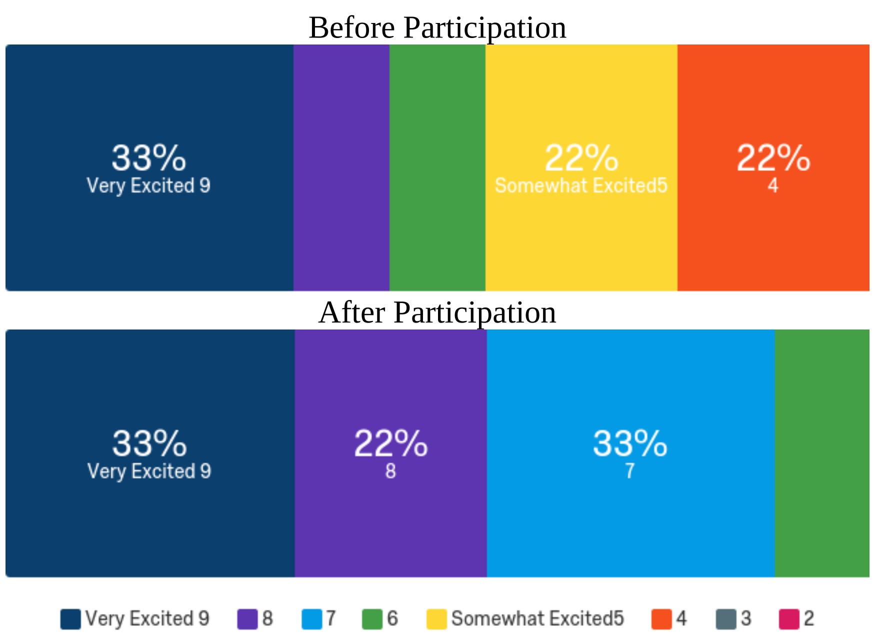

Figure 13. Excitement about area of participation, before (top) and after (bottom) participating.

Participants were also asked whether they attributed the changes that they reported to peer learning activity participation. As shown in Figure 14, over 75% of respondents attributed technical skill gains to activity participation. Similarly, as shown in Figure 15, over 75% of respondents attributed gains in excitement to program participation.

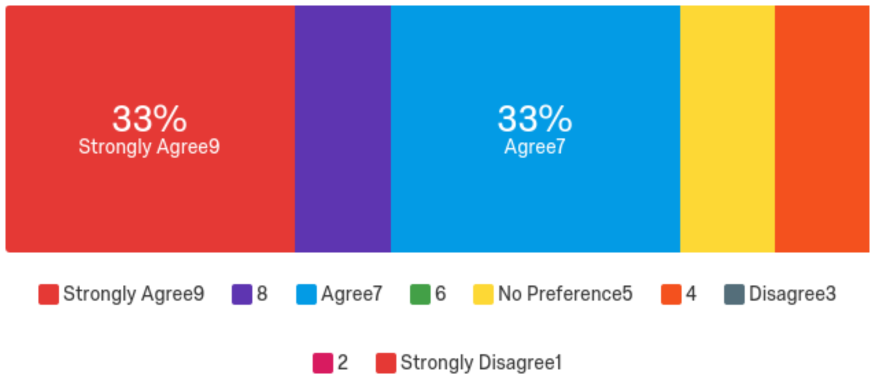

Figure 14. Belief that participation improved technical skills.

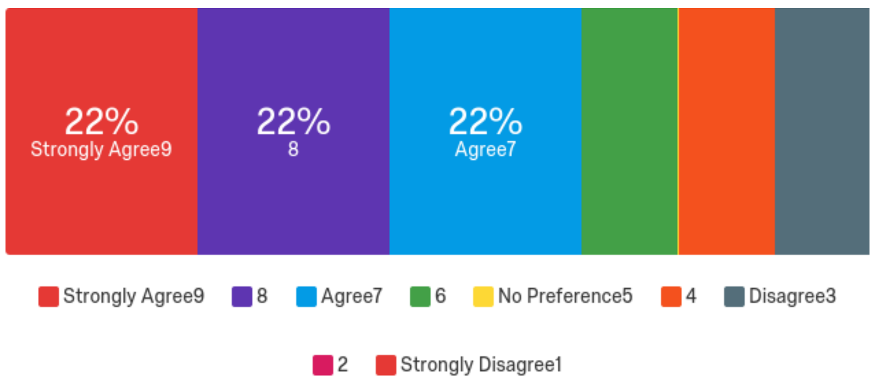

Figure 15. Belief that participation improved interest in area.

8. Conclusions and Future Work

This paper has discussed student-led peer learning activities related to cybersecurity at NDSU. It has characterized the benefits that students attained from these activities, showing that most students received benefit in multiple areas. In particular, technical skills, comfort in the technical area and excitement about the area were shown to have increased for most student respondents. Additionally, students indicated that they attributed these gains to activity participation.

These results demonstrate the potential for greater use of peer learning activities in the cybersecurity field. Given the shortage of instructors in this area, the effectiveness of peer learning may offer a solution for colleges that are unable to fully staff for their cybersecurity teaching needs. The ability to use peer learning to augment (or in some cases replace) instructional staff represents a potentially significant way to increase educational efficiency and program scalability.

This study considered only student-led peer learning activities. Instructor-directed or initiated activities would be required for the use of the technique as part of a formal educational (degree) program. Assessing the efficacy of peer learning in this environment remains a key area for and planned topic of future work.

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