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Emergent Research Forum (ERF)

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Introduction

Information security, which deals with "the protection of information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide integrity, confidentiality, and availability," (NIST n.d.) is an important concept in the information technology (IT) curriculum. Due to the diverse nature of the subject, which may range from conceptual topics such as the CIA (confidentiality, integrity, and availability) triad to technical topics such as the vulnerability in the encryption algorithm in WLAN network, the coverage of different information security topics is often spread out throughout the curriculum and being taught with various pedagogical methods. In recent years, process-oriented guided inquiry learning (POGIL), a form of guided collaborative learning approach has seen growing popularity in computing education with promising results (Hu and Kussmaul 2012; Hu and Shepherd 2013; C. Kussmaul 2012; C. L. Kussmaul 2012; Kussmaul et al. 2017; Yadav et al. 2019). However, existing practice with collaborative learning pedagogy in computing education primarily focuses on the subjects within a single course. The purpose of this research study is to determine if the collaborative guided learning pedagogy is a sound pedagogy for the diverse information security-related topics. The research questions of this study are:

- What is the general attitude of students towards the collaborative guided learning pedagogy?
- What factors affect students' interest in learning cybersecurity topics?
- What do students consider to be helpful during the learning experience?

Literature Review and Related Work

Literature has shown that collaborative and cooperative learning methods are effective in improving student learning and helping them develop key skills in both domain knowledge and "soft skills" in communication, problem-solving, teamwork/collaboration, and so on (Davidson 2014; Zheng and Li 2016). As a result, more and more instructors are adopting collaborative and cooperative learning methods in their teaching, which have changed teaching styles away from the traditional lecture format to student-centered active learning (Hein 2012; Zheng and Li 2016). Geiger (Geiger 2010) suggests that teachers can increase student success by replacing content laden lectures with team-based learning that promotes conceptual understanding and skill development.

The National Science Foundation (NSF) has funded several projects to study active learning and student-centered learning approaches in STEM that promote higher student involvement in the learning process. The guided collaborative learning approach was found to have a positive effect on the learning experiences for students who are new or have limited prior knowledge in chemistry (Vishnumolakala et al. 2017). A meta-analysis done by (Walker and Warfa 2017) has suggested that process-oriented guided inquiry learning (POGIL), which is a form of guided collaborative learning approach, can substantially increase students' odds of passing a course. In recent years, this guided collaborative learning process has been introduced to the field of computer science education to help students develop professional skills and prepare them for team-based upper-level courses such as capstone courses (Rahman and Dorodchi 2018). Researchers also suggested that the challenges, choices, options and approaches vary based on the class size, class modes, background of students, and the instructor preference (Rahman and Dorodchi 2018). In a most recent study, Yadav and colleagues (Yadav et al. 2019) conducted interviews with instructors who adopted the POGIL method in their computer science curriculum and the feedback from faculty suggests that POGIL helps with student retention, attendance and engagement, reduces isolation and improves student performance.

Research Design and Methods

Three learning activities on different subjects – input validation, security in operating systems, and SQL injection were designed and developed based on the principles of process-oriented guided inquiry learning. These three activities were then implemented in four different graduate-level courses in Summer and Fall 2019. The instructors chose the related security topics for the corresponding course. For example, the students enrolled in the database fundamental course learned SQL injection while the students enrolled in web development course learned input validation. As we expected, the students enjoyed the security topics and worked in groups in the classroom. In each group, there are 3 to 4 students and each perform a role during the learning activity. They are facilitator, spokesperson, quality control and process analyst. Students process the skills with critical thinking, communication, time management, research, problem solving, teamwork, and information processing. These students were enrolled in the hybrid courses that were 50% online and 50% face-to-face lectures.

Participants

Convenient sampling was used in this study. The participants consisted of students who were enrolled in the courses. Students were given a pre-survey prior to the start of the learning activity, and then a post-survey after the learning activity was done. Participation in the study was voluntary and students were free to opt-out of the pre- and post-survey.

Instruments

Both quantitative and qualitative data were gathered using the surveys. The surveys primarily consist of 5-Likert scale questions regarding their overall experience working in groups, their learning experience during the activity, and the level of knowledge and skills regarding the subject covered in the learning activity. Generic demographic information, such as gender and prior knowledge and experience, were also collected. Three open-ended questions at the end of the post-survey allow students to provide further details regarding their learning experience during the activity and also provide suggestions.

Results

To measure the outcomes of the collaborative guided learning for information security topics, we have conducted the pre-test and post-test survey. We started to use the learning materials for students from 2019 summer to the fall semester. Most participated students were graduate students who enrolled in the Master of Information Technology program. These students have limited experiences with cyber security topics, nor have they systematically learned about cybersecurity topics in the past.

Statistical Analysis

The total valid response rate is 84.1% for students who took both pre-survey and post-survey. 4.5% of the students disagreed to participate in the surveys. Among the respondents, student races are equally distributed in Asian, Black or Africa American, White, Two or more races, and other races. 52.38% of the respondents were female, and 45.24% were male, and 2.38% prefer not to say their gender. As shown in Table 1, the average student ratings on their learning experience regarding the activities are very positive.

	N	Min.	Max.	Mean	Std.
I think the learning experience is interesting	41	2	5	4.41	.836
I think the learning experience is good for me	41	2	5	4.39	.771
It gave me skills that will be helpful in my future career	41	2	5	4.20	.782
Valid N (listwise)	41				

Table 1. Student Ratings on Their Learning Experience

Unfortunately, the survey also revealed that only 31.71% respondents indicated that they take action to prevent cyber security incidents, 19.51% occasionally take the action, and 29.27% rarely take action (shown in Figure 1).

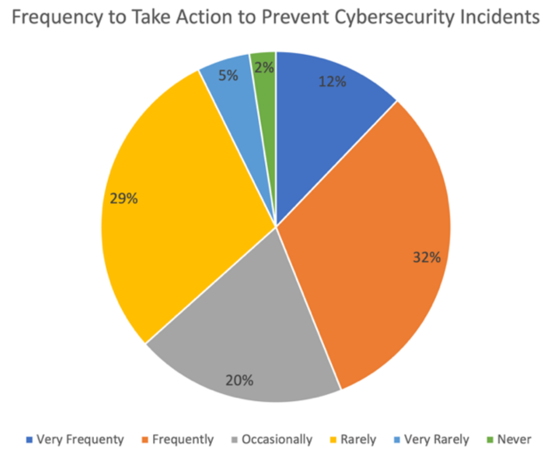

Figure 1. Frequency to Take Action to Prevent Cybersecurity Incidents

In addition to the descriptive statistics, we also investigated in the relationships among four variables: 1) concerns about cybersecurity incidents, 2) interests in learning about various topics of cybersecurity, 3) experiences working with groups in the course, and 4) learning motivation. Since we would like to increase students' interest in learning cybersecurity topics, the interest in learning cybersecurity is the dependent variable. Linear regression is used to investigate the relationships. The model is:

$$\text{Interests in learning cybersecurity topics} = \alpha_0 + \alpha_1(\textit{concerns about cybersecurity incidents}) + \alpha_2(\textit{teamwork experience in the course}) + \alpha_3(\textit{learning motivation}) + \varepsilon$$

Table 2 presents the summary of linear regression for the pre and post-survey. As shown in the table, pre-survey (R^2 = 0.572, RMSE = 0.475) has the better model fit than post survey (R^2 = 0.398, RMSE = 0.541). The model is statistically significant for both pre-survey (p value = 3.92E-07) and post-survey (p value = 0.0002).

Pre/Post	R Squared	Adj R Squared	RMSE	F Ratio	P Value
Pre	0.571504	0.537675	0.475042	16.89406	3.92E-07
Post	0.397995	0.349184	0.541244	8.153761	0.000271

Table 2. Summary of Linear Regression for Pre and Post Survey

In the coefficient table (Table 3), concerns about cybersecurity incidents lead to the interest in learning cybersecurity topics (p-value = 0.000 in pre-survey and p-value = 0.009 in post-survey). Regarding to the teamwork variable, the post-survey has become less important for the interests of learning (p-value = 0.723 in post-survey and p-value = 0.156 in pre-survey). The learning motivation is statistically significant to the interests (p-value = 0.000 in pre-survey and p-value=0.045 in post-survey).

Pre/Post	Term	Coefficient	Std Error	t Ratio	P Value
Pre	(Intercept)	-0.10	0.646	0.155	0.877
Pre	Concerns about cyber security incidents	0.543	0.117	4.638	0.000
Pre	Teamwork experience in the course	0.123	0.085	1.445	0.156

Pre	Learning motivation	0.414	0.107	3.844	0.000
Post	(Intercept)	1.274	0.686	1.856	0.071
Post	Concerns about cyber security incidents	0.471	0.172	2.734	0.009
Post	Teamwork experience in the course	-0.045	0.128	-0.357	0.723
Post	Learning motivation	0.281	0.135	2.074	0.045

Table 3. Coefficient Table for Pre and Post Survey

Qualitative Analysis

At the end of the post-survey, we asked participants about their experience in the activity and what they would consider to be the most helpful factor(s) in their learning experience. We text mined the comments from respondents by removing all the step words, converting the text to lowercase, stemming the words, and finding the token for each comment. TF-IDF (Term Frequency – Inverse Document Frequency) was then used for the analysis. The higher the TF value of a given term to a document, the more important the term is for the document. We found that the tokens “research”, “clear” and “team” are most mentioned to be helpful during the learning activities. Some example quotes from the responses are “external experience of my classmates”, “sharing ideas with team members”, “listening to other groups”, and “active discussion and examples”. In addition, students suggested more online videos and live examples about the security topics and more time to be given for the group learning activity.

Discussion

The respondents shared an overall positive attitude towards their learning experience in the three collaborative learning activities for information security related topics experimented in this study. Quantitative analysis shows that concerns about cybersecurity incidents and learning motivation have a strong correlation with student interest in learning cybersecurity topics. Qualitative analysis of student comments suggests that team experience helps students to better understand the security topics. Letting students get familiar with the materials in advance should enhance the learning experience since the preview can reduce confusion about the concepts. Based on the results from the survey, we will allow more time for group research sessions in our future implementation. Given that our IT graduate students come from diverse backgrounds and many of them do not have a bachelor’s degree in computing-related areas, how to attract and maintain student interest in the subject is highly important.

Conclusion

As shown in the paper, the collaborative guided learning pedagogy presents a valid option for teaching security-related topics. The positive learning experience will help better equip our students with broad knowledge of information security, which in turn will benefit the industry. For instance, a student may graduate and work for a company as a web developer, having a strong understanding of security issues related to web development will help the student build a more robust and secure web application that can better safeguard the data and potentially saving the company from losses in cybersecurity attacks. In addition, our study may also spark interests in fellow researchers who teach information security-related topics to adopt the collaborative learning pedagogy.

Limitation and Future work

Due to the limitation of the enrollment numbers, the sample size in the study is limited. The three learning activities developed and implemented are also limited in the representation of the vast diversity of information security-related topics. Also, existing effort in collaborative guided learning pedagogy primarily focuses on face-to-face interactions. How to effectively apply the collaborative guided learning pedagogy in the online environment remains a challenge and is worth exploring. We are currently in the process of developing more learning activities that can be adapted in the online learning environment. The investigation of the effectiveness of the collaborative guided learning pedagogy in the online setting will be the next stage of our research.

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