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Guided Inquiry Collaborative Learning (GICL) for Online Teaching in Cybersecurity: Challenges and Recommendations

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Abstract—The COVID-19 pandemic has required many educators to offer online courses. Given the evidence of the effectiveness of the Process-Oriented Guided Inquiry Learning (POGIL), many educators are interested in implementing POGIL in online environments. This paper first discusses the challenges of using the POGIL approach to teach courses. Then we share our experience and our proposed approach (GICL) for teaching cybersecurity topics via the Zoom platform in the online environment. Recommendations for overcoming some of these challenges for online teaching are provided.

Keywords—collaborative learning, online learning, POGIL, Process-Oriented Guided Inquiry Learning, Guided Inquiry Collaborative Learning

I. INTRODUCTION

Cybersecurity educators continue to show great interest in group learning[1]. This interest has been encouraged, for example, by the National Research Council's 2011 publication, "Cooperative Learning in STEM Education," and by the United States Congress itself (H. Res. 1-1-2-3-5-8-13, which designates the week of December 29 as National Cooperative STEM Learning Week). The National Science Foundation (NSF) has funded various projects to study active learning and consider student-centered learning approaches in STEM, each of which promotes greater student involvement in the learning process[2]. For example, Kusssmaul [3] used roles of manager, recorder, and speaker in his Data Structure classes to help students contribute evenly and express their multiple perspectives. Through a project funded by NSF, we have developed learning materials for teaching numerous topics in cybersecurity. Following the well-known POGIL guidelines [4], we have developed multiple guided inquiry collaborative learning activities

(available at <https://blog.utc.edu/li-yang/gicl/>). The detailed information of the activities is listed in Table I.

TABLE I. MULTIPLE GUIDED INQUIRY COLLABORATIVE LEARNING ACTIVITIES

Cryptography	Topic 1: Symmetric encryption Topic 2: Public key encryption Topic 3: Key Management
Access control	Topic 4: Discretionary access control (DAC) Topic 5: Mandatory access control (MAC)
Network Security	Topic 6: Secure Network Protocols – IPsec Topic 7: Secure Network Protocols – SSL Topic 8: Firewall Topic 9: Intrusion Detection Systems (IDSs)
Risk Management	Topic 10: Risk Analysis Part I and Part II
Web Security	Topic 11: Cross-Site Scripting & Defense Topic 12: SQL Injection and Mitigation
Secure Coding	Topic 13: Buffer overflow Topic 14: Input Validation Topic 15: Integer Vulnerability

The guided inquiry collaborative learning activity comprises several sections, including learning objectives,

key concepts of a small security topic, activity examples, critical thinking questions, exercise, discussion, and conclusion. In the classroom, four or five students work in one group; their instructors give them the guided inquiry collaborative learning activity. This activity helps them construct the knowledge they've learned in the class and stimulates their learning and research abilities while working on the assigned work.

The team members act in different roles, including recorder (recording all answers and questions and providing copies to the team and the facilitator); speaker (talking to facilitator and other groups); manager (keeping track of time and making sure that everyone contributes appropriately); and reflector (considering how the team could work and learn more effectively) while completing the guided inquiry collaborative learning activity (shown in Table II). Then, the team follows the instructions to complete the activity as a group, report what they learned from this activity, and provide answers to the questions listed on the sheet. This process helps students develop their responsibility and learn from each other. The instructor serves as the facilitator in each team.

TABLE II. TEAM ROLES IN GUIDED INQUIRY COLLABORATIVE LEARNING ACTIVITIES [5]

Team roles	Responsibilities
Recorder	Records answers and questions and providing copies to team and facilitator (instructor)
Speaker	Communicates with the facilitator and other teams
Manager	Monitors time and ensures that every group member contributes appropriately
Reflector	Summarizes and reflects on how group members could improve their work and learning

II. CHALLENGES USING POGIL FOR IN-PERSON TEACHING

Despite considerable evidence about POGIL's effectiveness in the literature [6]–[9], there are still some challenges in implementing POGIL activities in in-person classes. We reviewed the POGIL literature and summarized the following challenges in using POGIL for teaching in-person classes [5], [10].

- Curricular issues: it is more time-consuming than traditional lecture-based approaches
- Classroom space challenges: many classrooms are not designed to be suitable for the collaborative nature of POGIL
- Faculty's lack of experience in teaching POGIL
- Concern about the size of the group
- Accountability of the student role in the group activities: not all students may contribute equally to

the group discussion and work; student absences can make it difficult for group activities to continue, over several classes

- Lack of clarity about how to manage groups when some groups finish more quickly than other groups
- Students' gaps in knowledge, experience, and skills can make collaboration challenging

III. CHALLENGES IN USING GICL FOR ONLINE TEACHING

The COVID-19 pandemic has forced many universities to transition quickly to online instruction. There was little time for most instructors to carefully follow the best instructional design practices and design online courses for effective online teaching. This abrupt transition often resulted in students' dissatisfaction with their online course experiences at the beginning of the pandemic [11]. Barnes & Noble [12] surveyed 432 college students in the US on their perceptions about switching to online courses and found that students cared most about their lack of interaction with their fellow students and about their feelings of isolation as a result. Student engagement in online courses can be difficult to achieve [13]. Technology can be used to facilitate interaction and to engage students in online classes. However, technology cannot replace the support and facilitation of instructors. Online students reported that they struggled to stay motivated and that they had hoped to have more interaction with instructors and other students in an efficient way [14].

As online courses become more common, it is important to follow best practices to improve online course design and enhance students' online learning experiences, including interaction with other online students. In addition, equity and inclusion issues have received much attention during the pandemic, since some students have reported facing more challenges after their courses moved to online delivery [14].

To improve online engagement and interaction among students and ensure that each student would have an equitable opportunity while participating in online courses, we used the GICL approach in an online class using Zoom. Zoom offered an easy setup, a simple interface, and multiple connection methods. Numerous instructors and students used Zoom for their online courses, and their comfort level with this platform made the integration of GICL more seamless. In addition, students also could use Microsoft (MS) Teams, which provides secure access and platform for collaboration, for group activity. Students could also record their group meetings as needed.

Using this approach, we assigned four students to a group or an online breakout room. Each group member had a specific role in a GICL activity, as shown in Table II. Students followed the instructions and discussed and answered the questions listed on the Google Doc. The instructors and the teaching assistants rotated between different breakout rooms and facilitated synchronous group discussions. Students used asynchronous tools, such as

Google Docs and discussion boards, to post and share reports and summaries.

Pre survey and post survey were used in this study to evaluate the performance of our approach. We asked students, TA and instructors to fill up ques. We further used sentiment analysis and content analysis based on the open-ended questions to extract out the key insights and concerns that all stakeholder encountered.

We found that GICL encouraged students to raise questions and to participate more actively in group discussions than they would have during more traditional lecture classes sessions. As they did so, GICL provided equal opportunities for every group member to contribute to group discussions and intellectual collaborations. On the other hand, we also identified a list of challenges that we observed or received from students, teaching assistants (TA) and instructors. The detailed information of challenges is listed in Table III.

TABLE III. CHALLENGES FOR STAKEHOLDERS
IN ONLINE GICL ACTIVITY

Stakeholder	Challenges
Student	<ul style="list-style-type: none"> • motivation • distractions at home • technical interruptions • lack of effective communication with other team members • self-responsibility • poor internet access • prerequisite skills with online tools
Teaching Assistant	<ul style="list-style-type: none"> • needs training in facilitating online group activities and answering student questions • needs to be knowledgeable about the course content • needs to be responsible and dependable
Instructor	<ul style="list-style-type: none"> • must divide students into groups based on student experience, skills, abilities, etc. • needs to offer detailed instructions that can be easy to follow • needs skills in facilitating online group interaction, unpredictable attendance must be able to assess student work and performance • must understand teaching resource management, such as working with a very limited number of teaching assistants • must develop time management for the lessons

These issues were identified consistently in previous studies about adapting collaborative learning for online teaching [15]–[18].

IV. DISCUSSION

Despite these challenges, it is still possible to provide an engaging learning experience in an online environment through POGIL [19]. However, some adaptations and modifications are needed when using the GICL method and materials for online teaching. Preparation for online GICL teaching requires reflection, advanced planning, testing, and iterative revisions. Based on our experience in using GICL for teaching cybersecurity topics in both face-to-face and online courses, we provide the following suggestions:

1. Summarize experience and lessons from in-person courses

Holding an evaluation meeting to discuss the takeaways, lessons, and challenges in the in-person section is critical. This feedback and brainstorming could help instructors and TAs overcome some of the challenges and make the GICL activities more effective and efficient in the online learning environment. The goal is to aid students with their transition to the online course and to help them become comfortable with doing group activities in the online environment.

2. Plan in advance the process of implementing GICL online

A redesign of the teaching procedures is needed for the online format. Several essential steps to be taken are listed below:

- Identify appropriate technical tools: In order to reach students in an interactive online learning environment, for successful teaching and learning, effective and reliable technology is required to provide secure access and a platform for collaboration. To satisfy stakeholders with various levels of technological self-efficacy, a set of appropriate tools should be identified as keeping inclusion and equity is the priority.
- Internal training: Online teaching requires both instructors and teaching assistants to be familiar with online teaching tools and procedures. Internal training, not only about technical skills, but also soft skills (communication, teamwork, and adaptability) is equally essential.
- Utilizing synchronous and asynchronous tools: When the GICL activities are moved to the online format, it is better to adjust the way they will be taught. To conduct GICL activities in live online courses, video conferencing platforms like Zoom should be used to facilitate immediate communication among participants through a synchronized approach. On the other hand, if the courses allow schedule flexibility, group activities can be done by using asynchronous tools, although live online group meetings are still recommended.
- Reallocation of duties: Breakout rooms provided by video conferencing platforms have been widely used in online learning to facilitate group discussion. However, instructors often lose the direct interaction

with students when students are assigned to different breakout rooms. In this case, teaching assistants need to take on more responsibilities than they would in face-to-face (F2F) courses, leading students, coordinating group discussions, providing technical support, or answering students' questions.

3. Testing and iterative revision

The adaptation of the POGIL activities from an in-person class to an online GICL may not work as expected, especially for inexperienced students and instructors. Thus, iterations of internal testing are necessary to identify problems early on and resolve them in advance by making timely corrections. Detailed guidelines for instructors, TAs, and students should be developed to provide guidance and support. However, some problems, such as Internet instability, are unavoidable in the online environment. Thus, a contingency plan is required to address any unexpected situations. A recording of the online class or group meeting will be helpful for those who missed the class.

Moreover, since the key mean to facilitate the learning process is through effective communication among stakeholders, four dyads are highlighted in Fig. 1:

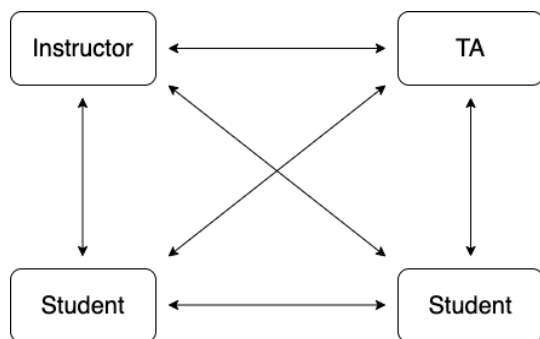


Fig. 1. Dyads in online GICL

- **Instructor and TA:** It is recommended that the instructor and the TAs meet online before the class to discuss how to prepare for the online course, and then meet again following the course's offering to discuss how to improve the online GICL activities for the next class, based on their experiences.
- **Instructor and Student:** The instructor should provide brief online lectures to students before asking them to complete the online GICL activities. It is important to answer students' questions and make sure that they understand the requirements, procedures, and what they need to complete during the group activities. Online chat tools or poll tools can be very useful in collecting questions from students. In addition, the instructor can also record video instructions first and upload the video to the Learning Management System (LMS), along with the necessary documents to explain group formation, roles and responsibilities, a study guide, and frequently asked questions. The instructor could

allow students to complete their group activity as a group at a time convenient to the group members. The instructor and TAs should offer flexible virtual office hours to better support students.

- **TA and Student:** When students are doing online GICL activities, TAs should play an active role in facilitating group activities. TAs not only need to assist students with the use of online tools and answer student questions during group activities, but they also need to coordinate and provide guidance to students in group discussions actively.
- **Student and Student:** Group discussions between students are at the core of the GICL approach. The use of online tools should ensure that students can communicate well with each other in terms of language, videos, and sharing documents. Collaborative tools like Google Docs and MS Teams are particularly useful.

V. CONCLUSION

Process-Oriented Guided Inquiry Learning (POGIL) has the potential to provide an equitable opportunity to improve student engagement and learning in online courses. In this paper, we discuss the challenges of using the POGIL approach to teach courses. Then we share our experience and our practices in adapting POGIL to teach cybersecurity topics, via the Zoom platform, in the online environment. Training for the facilitators, including both the instructor and any teaching assistants, should be provided to help them get ready for their first online GICL session. Advanced planning and preparation, including the set-up and testing of appropriate online technology tools, are needed, if the GICL sessions are to be run smoothly. In the planning for the course, instructors should choose whether the delivery mode will be synchronized or asynchronized. The asynchronized method will need more preparation, detailed documentation, and virtual office hours should be offered to support the students.

We hope that our experiences and suggestions will both spark interest and facilitate further research that will help educators better understand how to remove barriers to GICL implementation in their online classes.

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