2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #50583

Reimagining Cybersecurity Graduate Education Through Research-Based Role-Playing

Dr. Heena Rathore, Texas State University

Dr Heena Rathore is presently Assistant Professor in Department of Computer Science at Texas State University, San Marcos, Texas, USA. She formerly held positions as Assistant Professor of Practice at University of Texas at San Antonio and Visiting Assistant Professor at Texas A&M University at Texarkana. She has also worked as Data Scientist and Program Manager at Hiller Measurements, Austin. She received her Ph.D. from Indian Institute of Technology Jodhpur India while she was a Tata Consultancy Services Research Scholar. For her postdoctoral research, she worked on the US Qatar joint project on Medical Device Security, which included collaborators from Qatar University, the University of Idaho, and Temple University. Her research interests include cognitive AI, cybersecurity of cyber-physical systems, and biologically inspired systems. Dr. Rathore is IEEE Senior member, and chair for IEEE EMBS Lone Star Section. In the past, she has served as ACM Distinguished Speaker, Vice Chair for IEEE Central Texas Section. Her professional and research experience has led to several prestigious awards, including NI Global Engineering Impact Award, Educationist Empowering India, IEEE Region 5 Outstanding Individual Achievement Award, and many others.

Reimagining Cybersecurity Graduate Education Through Research-Based Role-Playing

Abstract

As cybersecurity education evolves to address the growing complexity of cyber-physical systems (CPS) and machine learning (ML)-driven threats, there is a pressing need for pedagogical approaches that integrate research immersion with experiential learning. This work presents findings from a graduate-level course (CS7389F) at Texas State University, which implemented a research-based role-playing framework to engage students in critical analysis, reproduction, and innovation of cybersecurity research. Students adopted one of five structured roles namely Reviewer, Archaeologist, Student Researcher, Reproducibility Checker, and Quanta Correspondent during a semester-long sequence of paper readings and projects. The study measured students' perceptions before and after course completion using pre- and post-surveys (N = 18 pre; N = 16 post). Quantitative analysis of role preference distributions revealed that Student Researcher and Reviewer roles gained prominence post-intervention, reflecting increased engagement with authentic research practices and critical evaluation. Chi-square tests (χ^2 = 1.03, p = 0.91) indicated stable distributional trends overall, but descriptive shifts highlighted deeper identification with research-contributing roles. Qualitative feedback corroborated these findings, emphasizing that the role-based framework enhanced students' confidence in reviewing, replicating, and extending published studies. This approach demonstrates how graduate cybersecurity education can transition from content transmission to research apprenticeship, cultivating higher-order competencies in evaluation, reproducibility, and innovation.

Introduction

Cybersecurity has become a foundational concern for modern society, as critical infrastructures, cyber-physical systems (CPS), and machine-learning–enabled services are increasingly targeted by sophisticated adversaries. Graduate programs in computer science and engineering are expected not only to teach the technical foundations of security, but also to cultivate professionals who can critically interpret research, evaluate emerging techniques, and design novel defenses in rapidly evolving threat landscapes. This is especially true in domains such as CPS security and applied cryptography, where attacks and defenses co-evolve quickly and textbooks lag behind the state of the art[1-3]. Preparing students to participate meaningfully in this research ecosystem requires pedagogical approaches that move beyond lecture-driven content delivery and toward authentic engagement with current literature, tools, and open problems.

In response, a variety of educational strategies have been adopted within cybersecurity programs. Hands-on laboratories, cyber ranges, and capture-the-flag (CTF) competitions give students practical exposure to vulnerabilities and exploits, while project-based courses and inquiry-driven assignments develop design and implementation skills[3]. More broadly, the learning sciences emphasize cooperative and team-based approaches such as structured group work, the jigsaw method, and team-based learning to promote higher-order thinking, accountability, and engagement[10-14]. Within this space, role-playing has emerged as a powerful technique in multiple disciplines—including business, health, and professional education—for developing cognitive, affective, and behavioral competencies through simulated practice, perspective-taking, and reflection[4-9].

Several initiatives have explored role-playing and structured paper-reading within graduate education. Classic graduate seminars use student-led paper presentations and discussions to cultivate skills in technical reading, critique, and scholarly communication[15], while recent work by Jacobson and Raffel introduced role-playing paper-reading seminars where students assume complementary roles around each paper (e.g., reviewer, implementer, futurist)[6]. Such innovations recognize that research competence requires more than summarizing papers; it also involves situating contributions, assessing empirical evidence, replicating methods, and imagining follow-up work. However, these approaches are often limited to stand-alone seminars or loosely structured reading groups, with relatively little attention to systematic integration into core graduate cybersecurity coursework.

Several important gaps remain. First, there is limited work that systematically structures research engagement through explicit, complementary roles embedded into a full graduate cybersecurity course rather than a stand-alone seminar. Second, the research-oriented activities that do exist such as term projects or literature reviews rarely foreground reproducibility, research identity formation, or the full lifecycle from critique to extension of a paper. Third, empirical evidence about how different kinds of research roles are perceived by graduate cybersecurity students, and how those perceptions evolve over a semester, is sparse. In particular, little is known about which roles students gravitate toward, which they see as most impactful for advancing security research, and how structured role-based experiences shape these preferences over time.

This paper addresses these gaps by designing, implementing, and evaluating a research-based role-playing framework within a graduate-level cybersecurity course, CS7389F, focused on secure CPS, cryptography, and machine learning. In this framework, students engage with contemporary research papers through five deliberately defined roles Reviewer, Archaeologist, Student Researcher, Reproducibility Checker, and Quanta Correspondent and then conduct a course project aligned with these roles. We present the pedagogical design of this approach, describe its integration into lectures, discussions, and projects, and report results from pre- and post-course surveys in a single graduate cohort. The analysis characterizes how students' preferences and perceived impact of different roles shift over time, and how they respond to structured opportunities for reviewing, reproducing, and extending security research. Through this case study, we aim to provide a model for embedding authentic research practices into graduate cybersecurity education and to offer evidence-informed guidance for instructors seeking to cultivate research-ready security professionals.

Background and Related Works

The rapid growth of CPS has expanded the attack surface beyond traditional IT environments into domains such as transportation, healthcare, industrial control, and smart cities. This expansion has driven calls for more comprehensive cybersecurity education across educational levels[1]. Within higher education, research has examined the landscape of cybersecurity education papers and identified needs for more systematic integration of real-world case studies, hands-on environments, and research-aligned activities[3]. Prior work has also explored ways of embedding CPS security concepts into undergraduate security courses, emphasizing the need to connect theory with domain-specific threats, architectures, and constraints[2].

Graduate-level cybersecurity courses, particularly those involving CPS and ML, demand even more advanced competencies. Students must be able to navigate a fast-moving literature, critically evaluate experimental methodologies, and reason about the limitations and generalizability of published results. However, many courses still rely heavily on lectures and problem sets, with limited structured exposure to the research process itself.

Cooperative learning and structured group work have long been recognized as effective strategies for promoting critical thinking, accountability, and interpersonal skills[10-11]. Techniques such as the jigsaw classroom divide a complex topic into sub-topics, assigning each student to become an "expert" on one part and then teach it back to their peers[13-14]. Team-based learning similarly stresses carefully designed roles, preparation, and peer evaluation to ensure productive collaboration[11].

Role-playing builds on this tradition by asking learners to inhabit specific perspectives in simulated or real-world scenarios. In higher education, role-play has been used to develop professional judgment, communication skills, and empathy, and has been found to support learning in cognitive, affective, and behavioral domains[4,7,8]. Studies in fields such as construction management, leadership training, and healthcare report that role-playing can enhance student engagement and transfer of learning to practice[5,9].

Within computing and related disciplines, graduate seminars often rely on student-led paper readings and discussions to build research skills[15-16]. Traditional one-to-many presentation formats, however, can leave non-presenting students relatively passive and may underemphasize critical analysis[16]. Jacobson and Raffel's role-playing paper-reading seminar model intentionally assigns complementary roles (e.g., reviewer, implementer, futurist, skeptic) to ensure that each student engages with a paper from a distinct research-relevant perspective and contributes actively to discussion[6].

An initial implementation of the research-based role-playing framework was introduced at IEEE ISEC 2025, where it was deployed across both undergraduate and graduate cybersecurity courses to examine cross-level differences in role preferences and experiential learning outcomes[12]. That work demonstrated the feasibility and pedagogical value of structured role-based paper discussions within non-seminar security courses. Building on those findings, the present study advances the framework in three important ways: (1) it concentrates exclusively on graduate cybersecurity education, where research readiness is a primary objective; (2) it formalizes the approach as a research apprenticeship model grounded in learning sciences; and (3) it incorporates

explicit research questions, statistical analysis, and structured evaluation of role-based identity formation. This approach is particularly promising for cybersecurity, where research often requires cross-cutting skills: reading and critiquing papers, reproducing code and experiments, understanding prior work, and envisioning new attacks or defenses. Yet, there is little empirical work examining how graduate cybersecurity students respond to such role-based structures, which roles they find most meaningful, or how these perceptions evolve over time.

1 Methods

The research-based role-playing framework implemented in CSX7389F was structured around five complementary roles designed to collectively capture the full lifecycle of cybersecurity research (See Figure 1). The Reviewer role emphasizes critical evaluation, requiring students to assess research questions, methodologies, datasets, evaluation metrics, and limitations using conference-style review criteria. The Archaeologist role focuses on situating a paper within its scholarly context by tracing foundational prior work and identifying subsequent research that builds upon or critiques the study. Through the Student Researcher role, students engage in ideation and innovation by formulating new research questions and proposing extensions or improvements to existing work. The Reproducibility Checker role highlights the importance of validation and scientific rigor by tasking students with replicating published results and examining the feasibility, robustness, and transparency of reported experiments. Finally, the Quanta Correspondent role develops communication skills by challenging students to translate complex technical contributions into accessible narratives for a broad audience, emphasizing societal relevance and impact.

Figure 1: Five-Role Framework

The study addressed the following research questions in the context of CS7389F:

- RQ1: How do graduate students' preferences for different research roles change over the duration of a role-based paper-reading and project framework?
- RQ2: How do graduate students' perceptions of which roles have the greatest potential to expand the scope and impact of research change from the beginning to the end of the course?

- RQ3: How do students describe the benefits and challenges of engaging in research-based role-playing within a graduate cybersecurity course?

Data were collected from a single Spring offering of CS7389F. Pre-course and post-course surveys were administered online. For the focal item on perceived impact (RQ2), 16 usable pre-survey responses and 18 usable post-survey responses were available from the CS7389F cohort. The survey instrument included both closed-ended and open-ended items. Two key multiple-choice questions asked students:

- Q1 (Discussions/ Group Project): Which part are you excited more (pre)/ which aspect of course did you like more? (post)
- Q2 (Excited Role): Which role are you most excited about when engaging with a research paper? (pre) / Which role did you like the most when engaging with a research paper? (post)
- Q3 (Perceived Impact): Which role do you believe has the potential to significantly expand the scope and impact of the research? (pre and post, with parallel wording).

Each question listed the five roles: Reviewer, Archaeologist, Student Researcher, Reproducibility Checker, and Quanta Correspondent. Open-ended prompts invited comments on what students found most valuable or challenging about the role-based structure, and how it affected their confidence in reading, reproducing, or extending research papers. In addition, standard course evaluation comments provided qualitative insights into student experience. For each question and time point, frequency and percentage distributions were computed across the five roles.

For all the research questions, we relied on reported aggregate distributions for the CS7389F cohort because wording differences between the pre- and post-items ("which part are you excited about more" versus "which role did you like the most") limit direct inferential comparison. An unpaired chi-square test of independence was used to test whether the distribution of perceived impact across roles differed significantly between pre- and post-survey responses. Only complete responses on the impact item were used (16 pre, 18 post).

2 Results

2.1 RQ1: Discussion vs Group Project Preferences

Across both pre and post survey items, graduate students showed a clear and consistent preference for discussion-based activities over individual or group projects. When asked which aspect of the course they liked more (18 responses), 72.2% of students favored discussions, while 27.8% preferred the individual/group project component (See Figure 2). A similar trend appeared in responses to which part of the course students were more excited about (16 responses), where 73.3% selected discussions compared to 26.7% who chose the individual/group project. Together, these results indicate that research-oriented discussions particularly those structured around role-based paper reading were perceived as more engaging and enjoyable than project work, underscoring the value of interactive, dialogue-driven learning experiences in graduate cybersecurity education.

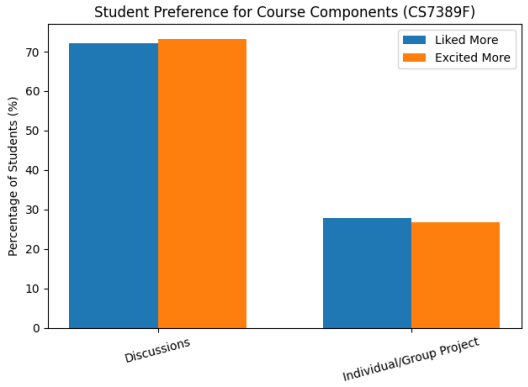

Figure 2: Student Preference for Course Components (CS7389F)

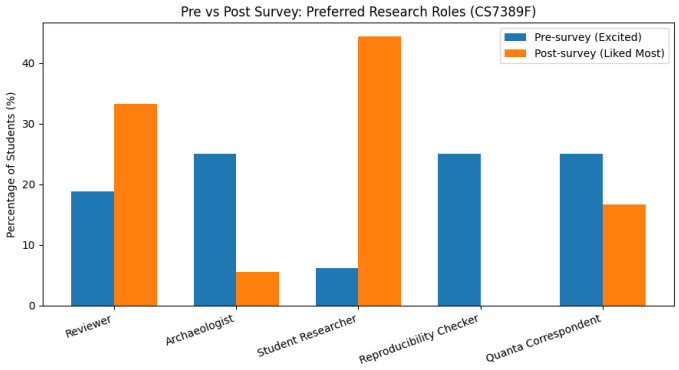

Figure 3: Pre- and post-survey comparison of graduate students' preferred research roles in CS7389F. Results show a marked post-course shift toward the Student Researcher and Reviewer roles, with reduced preference for the Reproducibility Checker role, indicating increased identification with roles emphasizing research ideation and critical evaluation.

2.2 RQ2: Excited Role Preferences

Analysis of the CS7389F cohort showed a substantial shift in the roles that students found most exciting over the course of the semester. At the beginning of the course, excitement was relatively evenly distributed across the Archaeologist, Reproducibility Checker, and Quanta Correspondent roles (each attracting roughly one-quarter of responses), with fewer students initially excited about acting as Reviewer or Student Researcher. By the end of the course, this pattern changed markedly. Approximately half of the students reported that Student Researcher was their favorite role, with an additional substantial fraction preferring Reviewer; only a small minority continued to prefer Archaeologist, and none selected Reproducibility Checker as their favorite role. Quanta Correspondent remained of interest to some students but was no longer a dominant choice (See Figure 3).

Taken together, these findings suggest that as students gained experience with the research lifecycle proposing follow-up ideas, reviewing papers, and working on projects they increasingly identified with roles that emphasize active contribution to research (Student Researcher) and critical evaluation (Reviewer), rather than roles focused primarily on historical context or implementation effort.

2.3 RQ3: Perceived Impact of Roles on Research

For Q3, we examined which role students believed has the greatest potential to expand the scope and impact of research. Table 1 summarizes the pre- and post-survey counts (16 pre, 18 post usable responses).

Table 1: Pre- and post-survey counts for perceived high-impact research roles (CS7389F)

Role Category	**Pre-Survey**	**Post-Survey**
Student Researcher	8	8
Reproducibility Checker	3	4
Archaeologist	2	1
Reviewer	2	4
Quanta Correspondent	1	1
Total Responses	16	18

Statistical analysis: A chi-square test of independence comparing pre- and post-survey role distributions yielded $\chi^2 = 1.029$ with 4 degrees of freedom ($p = 0.9054$), indicating no statistically significant change in the overall distribution of perceived high-impact roles.

Student Researcher was the most frequently selected high-impact role at both time points (50% of pre-survey responses and 44% of post-survey responses). The proportion of students selecting Reproducibility Checker and Reviewer increased modestly from pre to post, while selections for Archaeologist declined and Quanta Correspondent remained low. A chi-square test of independence comparing the pre and post distributions across the five roles yielded χ^2 = 1.03 with 4 degrees of freedom and p = 0.91, indicating no statistically significant change in the overall distribution at conventional significance thresholds. Nonetheless, the descriptive pattern (Figure 4) aligns with the qualitative impression that students maintain a strong belief in the centrality of

the Student Researcher role, while developing greater appreciation for the role of reproducibility and rigorous reviewing in advancing the field.

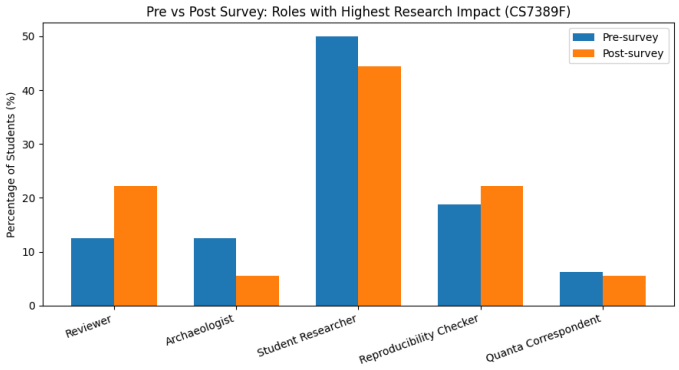

Figure 4: Pre- and post-survey comparison of graduate students' perceptions of which research roles have the greatest potential to expand the scope and impact of cybersecurity research in CS7389F. The Student Researcher role remains dominant across both surveys, while perceptions of the Reviewer and Reproducibility Checker roles increase modestly post-course.

Qualitative feedback from surveys and course evaluations provides additional insight into how students experienced the role-based framework. Several themes emerged:

- Increased confidence and research identity. Students reported that repeated practice with reviewing and proposing follow-up projects made them feel more capable of reading and critiquing research papers, and more prepared to contribute to ongoing work in security and high-performance computing. One student noted that the combination of rigorous paper reviews and clearly defined roles gave them "a strong base in machine learning and cybersecurity implementation" and helped them see themselves as a researcher rather than just a consumer of results (paraphrased from course evaluations).
- Value of structure and variety. Many students appreciated that the roles provided clear expectations and shifted them out of their comfort zones. Having to alternate between, for example, explaining a paper to a broad audience (Quanta Correspondent) and proposing a new research idea (Student Researcher) fostered a more holistic understanding of the research process.
- Reproducibility as challenging but insightful. While few students selected Reproducibility Checker as their favorite role by the end of the course, comments highlighted that the replication work was eye-opening and underscored the importance and difficulty of reproducing published results. Students noted that getting code to run and aligning experimental settings required substantial effort, but that this work deepened their understanding of both the paper and the limitations of empirical claims.
- A smaller set of comments pointed to the time demands of juggling multiple roles, readings, and a challenging project. Students generally framed this workload as "demanding but worthwhile," though some suggested providing more scaffolding or examples early in the course. Overall, student feedback suggests that the research-based

role-playing framework was perceived as demanding yet highly valuable, especially in building confidence with reviewing, communicating, and extending research.

Discussion

2.4 Interpreting Role Shifts in Graduate Research Development

The observed shift in excited role preferences from relatively balanced interest across roles to a strong preference for Student Researcher and Reviewer suggests that immersive exposure to research-like tasks can help students gravitate toward roles that align more closely with the core practices of academic cybersecurity. Early in the course, roles such as Archaeologist, Reproducibility Checker, and Quanta Correspondent may feel more concrete and accessible; over time, however, students gain experience proposing new ideas, assessing contributions, and connecting their projects to open problems, which makes the Student Researcher and Reviewer roles more salient and appealing.

For perceived impact, the stability of Student Researcher as the dominant role is unsurprising: students intuitively see generating new ideas and contributions as central to research. The modest increases for Reproducibility Checker and Reviewer, even without statistically significant distributional change, are noteworthy given the well-documented importance of reproducibility and critical peer review in security and ML research. The role-based framework appears to make these practices more visible and valued, even if students do not ultimately find the corresponding roles to be the most "exciting."

2.5 Design Implications for Cybersecurity Instructors

Several design principles emerge for instructors seeking to embed research-based role-playing into graduate cybersecurity courses:

- The five roles used in CS7389F map naturally onto key phases of research: situating work (Archaeologist), critical evaluation (Reviewer), replication (Reproducibility Checker), ideation and extension (Student Researcher), and communication (Quanta Correspondent). Explicitly connecting these roles to real conference and journal practices can help students see how classroom activities mirror professional research workflows.
- Requiring students to experience multiple roles supports broad skill development, while encouraging them to invest deeply in select roles (e.g., Student Researcher and Reproducibility Checker for the project) fosters mastery and ownership.
- Selecting papers from current CPS, ML, and LLM security research ensures that students engage with live debates, incomplete solutions, and non-trivial implementation challenges, which can be more motivating than textbook examples.
- Students often find replication work challenging; providing starter code, environment setup guidance, or exemplars of replication reports can make this role more approachable while preserving its educational value.

- Short written reflections or debrief discussions can help students articulate what they learned from each role, how their perceptions of research are changing, and which skills they want to develop further.

3 Limitations and Future Work

This study has several limitations. It is based on a single course offering at one institution with a relatively small graduate cohort, which limits generalizability. Pre- and post-survey response counts differ slightly across items, and the wording change for the excited role item (Q1) complicates inferential comparisons. The analysis relies primarily on self-reported preferences and perceptions rather than direct measures of learning outcomes or long-term impacts on research productivity or career trajectories.

Future work will extend this framework in several directions. First, we plan to apply the same role-based structure in additional offerings of CS7389F and in related graduate or advanced undergraduate courses (e.g., general computer security, AI security) to examine robustness across contexts. Second, we aim to refine the survey instrument by adding validated scales of research self-efficacy and integrating stable respondent identifiers (while preserving anonymity) to enable paired analyses over time. Third, we are interested in integrating AI-assisted tools for example, large language models acting as draft reviewers or "AI archaeologists" to support students in certain roles while maintaining human critical oversight. Finally, a multi-institutional study could compare how students from different backgrounds and program structures respond to research-based role-playing in cybersecurity.

4 Conclusion

As cybersecurity threats become more complex and intertwined with CPS and ML, graduate education must prepare students to be not only skilled practitioners but also capable researchers and critical consumers of the literature. This paper presented a research-based role-playing framework implemented in a graduate cybersecurity course and reported survey-based evidence on how students' role preferences and perceptions of research impact evolve over a semester. The findings indicate that students increasingly identify with the Student Researcher and Reviewer roles and maintain a strong belief in the importance of these roles for advancing research, while also developing a greater appreciation for reproducibility. Student comments suggest that the framework, though demanding, supports the development of research identity and confidence. For instructors, the results highlight the promise of structured roles as a mechanism for aligning classroom activities with authentic research practices, particularly in fields like cybersecurity where the knowledge frontier moves quickly. By intentionally designing courses that ask students to read, review, reproduce, extend, and communicate research, educators can help cultivate the next generation of cybersecurity researchers and professionals.

References

[1] N. A. A. Rahman et al., "The importance of cybersecurity education in school," International Journal of Information and Education Technology, vol. 10, no. 5, pp. 378–382, 2020.

[2] H. Rathore, “Integrating cyber physical system security concepts in computer system security curriculum,” in 2023 IEEE Integrated STEM Education Conference (ISEC). IEEE, 2023, pp. 397–399.

[3] V. Svábenský, J. Vykopal, and P. Čeleda, “What are cybersecurity education papers about? A systematic literature review of SIGCSE and ITiCSE conferences,” in Proceedings of the 51st ACM Technical Symposium on Computer Science Education, 2020, pp. 2–8.

[4] D. Rao and I. Stupans, “Exploring the potential of role play in higher education: Development of a typology and teacher guidelines,” Innovations in Education and Teaching International, vol. 49, no. 4, pp. 427–436, 2012.

[5] O. A. Sogunro, “Efficacy of role-playing pedagogy in training leaders: Some reflections,” Journal of Management Development, vol. 23, no. 4, pp. 355–371, 2004.

[6] A. Jacobson and C. Raffel, “Role-playing paper-reading seminars,” 2021.

[7] H. W. Maier, “Role playing: Structures and educational objectives,” The International Child and Youth Care Network, vol. 36, 2002.

[8] U. Westrup and A. Planander, “Role-play as a pedagogical method to prepare students for practice: The students’ voice,” Högre Utbildning, vol. 3, no. 3, pp. 199–210, 2013.

[9] S. Bhattacharjee, “Effectiveness of role-playing as a pedagogical approach in construction education,” in 50th ASC Annual International Conference Proceedings, vol. 1, no. 1, 2014, pp. 81–105.

[10] D. W. Johnson and R. T. Johnson, “Social skills for successful group work,” MAA Notes, pp. 201–204, 1997.

[11] M. Sweet and L. K. Michaelsen, Team-Based Learning in the Social Sciences and Humanities: Group Work that Works to Generate Critical Thinking and Engagement. Taylor & Francis, 2023.

[12] H. Rathore and H. Griffith, ”Enhancing Cybersecurity Education Through Research-Based Role-Playing,” 2025 IEEE Integrated STEM Education Conference (ISEC), Princeton, NJ, USA, 2025, pp. 1-6, doi: 10.1109/ISEC64801.2025.11147262.

[13] N.-P. Apostol, “King Henry VIII and his life story: Jigsaw reading,” The Journal of Linguistic and Intercultural Education, vol. 6, p. 43, 2013.

[14] E. Aronson et al., The Jigsaw Classroom. Sage, 1978.

[15] S. Steen, C. Bader, and C. Kubrin, “Rethinking the graduate seminar,” Teaching Sociology, vol. 27, no. 2, pp. 167–173, 1999.

[16] L. He, E. Sanocki, A. Gupta, and J. Grudin, “Comparing presentation summaries: Slides vs. reading vs. listening,” in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2000, pp. 177–184.