Work in Progress: Exploring Peer Support and Higher-Order Thinking in a Flipped Project-Based Cyber-Aerial Computing Course

Mrs. Burcu Stone, Texas Tech University

Burcu Stone is a doctoral candidate in Instructional Technology at Texas Tech University and a Program Manager at Texas Tech University Online. Her research focuses on instructional strategies for student-centered learning, such as game-based learning and blended/personalized learning, project-based learning, and design-based research in higher education.

Deniz Bulut, Texas Tech University

Deniz Bulut is a doctoral student and research assistant in the Educational Instructional Technology Program at Texas Tech University, specializing in teacher education and instructional design research.

Felix Mulei Mule, Texas Tech University

Felix Mulei Mule is a doctoral candidate in Instructional Technology at Texas Tech University. My interests are in student-centered learning and project-based and blended learning. My work bridges evidence-based design with workforce-aligned training to improve learner engagement and outcomes.

Dr. Sungwon Shin, Texas Tech University

Sungwon Shin is an Associate Professor of Instructional Technology at Texas Tech University.

Mihwa Park, Texas Tech University

Dr. Mihwa Park is an Associate Professor of STEM education at Texas Tech University. Her research interests involve developing measurement instruments to assess students' understanding of scientific concepts and their emotions when learning science. She is also interested in teachers' emotions about teaching science and teacher identity.

Dr. Sunho Lim, Texas Tech University

He is an Associate Professor in the Department of Computer Science, Texas Tech University. His primary research interests are in the areas of Cyber Aerial Computing, Mobile Data Privacy, and Wireless Networks and Mobile Computing. He is a senior member of the IEEE.

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Abstract

This work-in-progress (WIP) paper is part of a Design-Based Research (DBR) project in an undergraduate course, Cyber-Aerial Computing, which integrates drone technology to teach embedded programming while promoting ethical awareness around privacy and security through flipped learning (FL) and project-based learning (PBL). Employing 17 junior and senior undergraduate computer science (CS) students working in pairs, the focal point of this study was to investigate the role of peer support in facilitating student learning and developing higher-order thinking skills such as critical thinking, problem-solving, analysis and synthesis through collaboration during drone-centered programming tasks. Data collected through focus group interviews and mid-course and post-course surveys revealed that students frequently engaged in task-related discussions, explanation-seeking, and collaborative troubleshooting, indicating active cognitive engagement and mutual scaffolding during lab activities. The findings suggest that structured peer support carries a potential to enhance students' persistence, problem-solving abilities, and ethical awareness in addressing privacy and security issues within drone computing.

Introduction

Learning is increasingly perceived as a socially situated process rather than an exclusively individual endeavor [1], [2]. Across decades of educational research, scholars have emphasized the importance of *social relationships* in supporting high-quality learning experiences, highlighting the role of collaborative learning environments in fostering engagement, agency, and student well-being [3]. Within such environments, peers play a central role by providing opportunities for dialogue, feedback, and mutual support that enable learners to progress through complex academic tasks.

Peer interactions contribute to learning quality by supporting cognitive engagement and sustained participation [4], [5]. Through explanation-seeking, task-related discussion, and collaborative problem-solving, learners are able to externalize their thinking, refine understanding, and scaffold one another's learning. These processes are closely associated with the development of higher order thinking skills, including analysis, synthesis, and problem-solving, particularly in learning contexts that require sustained effort and coordination among learners [6], [7]. The role of peer-supported learning and peer interactions has been accentuated particularly in engineering education as it continues to grow in response to rapid technological advancement and increasing global complexity [8], [9]. To keep up with the evolving trends and expanding needs, engineering graduates are now expected to demonstrate not only technical expertise but also a broad range of competencies such as communication, collaboration, critical thinking, and ethical reasoning, which are also known as higher order thinking skills [10]. To meet the demands of real world and equip engineering students with the diverse skills and competencies, engineering education has increasingly shifted toward active learning approaches including cooperative learning, peer teaching/mentoring, and project-based learning, which proved to more effectively support the development of transferable skills essential for professional practice [5], [9], [11], [12].

Motivation for Research

Within the context of engineering education, *peer support* has emerged as a key construct for promoting learning and creating collaborative learning environments [13]. As a sub-category of the concept of peer learning which is "*the use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher*" [14], peer support involves the exchange of cognitive, emotional, and social interaction among students, demonstrated in the form of information sharing, empathy, encouragement, and collaborative problem-solving [6], [7]. Understanding how peer support operates is particularly important in engineering education, where teamwork and collaborative problem-solving are foundational professional competencies [4]. Despite growing interest in peer support and active learning approaches, the existing literature is limited to studies of formal or informal peer instruction manifested as peer mentoring, peer teaching, and peer tutoring in the context of engineering [8], [15], [16], [17]. The question of how structured, one-on-one peer support influences learning processes and outcomes in complex, technology-rich engineering contexts that also foreground ethical considerations is still a matter of investigation.

Motivated by this gap, this work-in-progress study investigated the role of peer support in an undergraduate computer science (CS) course that integrated drone technology to teach embedded programming while addressing ethical issues related to privacy and security. The guiding research question was: *What role does peer support play in students' successful completion of drone-related projects in a flipped project-based learning environment?* In light of the Design-Based Research (DBR) framework, the study examined how structured peer support experiences shape students' engagement, persistence, and higher-order thinking during drone-centered programming tasks implemented through flipped learning (FL) and project-based learning (PBL). By examining the role of peer support through peer interactions, the study aimed to generate design-relevant insights for engineering educators seeking to create collaborative learning environments that support both technical learning, higher order thinking skills, and ethical considerations required of future engineers.

Summary of the Intervention

This 14-week CS course at a four-year university in the southwestern region of the United States was designed to introduce undergraduate students to aerial computing, cybersecurity, and Sky-of-Privacy-Things (SoPT) to help them apply their computer science knowledge to drone technologies to protect and benefit communities and society. During the semester, students engaged with asynchronous online materials in the FL environment to build foundational knowledge in drone technologies, aerial networks, algorithms and communication protocols, privacy, and cybersecurity. This was followed by weekly in-person lab sessions where students designed, programmed, and tested drone-based solutions, progressing through project milestones that mirrored real-world challenges.

A total of 20 students from CS, computer engineering, and mechanical engineering enrolled in the course in Fall 2025, and 17 of them granted their consent to take part in this research study. The course was structured into two groups, Group A and B, each group consisting of five pairs working together throughout the semester for increasingly complex drone programming and data analysis projects. Peer interactions in lab sessions were observed by three researchers to capture communication patterns, teamwork behaviors, and instances of higher-order thinking. In addition, mid-course and post-course surveys *(N = 17)* and focus group interviews *(N = 7)* were conducted to explore students' perceptions of peer support and its influence on their technical expertise and ethical awareness (see Appendix for the sample focus group interview questions and sample survey items).

Summary of Findings

Having employed a mixed-methods design, this study incorporated various data sources such as focus group interviews, mid-course surveys, and post-course surveys to investigate the effectiveness of peer support. While thematic analysis was conducted for the focus group interviews, survey responses will be examined using descriptive statistics for close-ended items and content analysis for open-ended responses. This paper reports preliminary qualitative findings from focus group interviews, which inform ongoing analysis of survey data and future design iterations within the DBR cycle.

Focus Group Interviews

The analysis of the focus group interview data collected from 7 participants revealed that peer support played an integral role in students' successful completion of drone-related programming projects. Students consistently described peer support as a multifaceted mechanism that supported learning by scaffolding complex problem-solving, organizing collaborative work, promoting higher-order thinking, sustaining motivation and persistence, and mitigating logistical and technical challenges.

Table 1

Summary of Focus Group Findings on Peer Support

Category	Role of Peer Support	Key Processes Observed	Representative Quotes
Forms of Peer Support	Enables task completion through cognitive, emotional, and social scaffolding	Collaborative debugging, error checking, trust and rapport	"We just, like, assisted each other anywhere… like saw bugs or something."
Task Coordination	Structures work efficiency and continuity	Role specialization, flexible role switching, in-class and asynchronous collaboration	"I was usually, like, doing the code… and then she was doing more like the report."
Higher-Order Thinking	Promotes problem-solving, analysis, and diagnostic reasoning	Iterative trial-and-error, hardware–software diagnosis, documentation use	"Is it hardware issues and software issue?"
Motivation & Persistence	Sustains engagement through difficulty	Persistence until success, emotional reward, increased confidence	"Just to not, like, give up until it's working."

Challenges & Constraints	Mitigates logistical and technical barriers	Scheduling adaptation, uneven participation management, technical troubleshooting	"The firmware on the drone itself needed to be updated."
Peer Environment	Extends learning beyond pairs	Observational learning, solution diffusion, non-competitive climate	"Seeing another group figure it out… I know I can do that now."

Peer Support for Task Completion

Students emphasized that working with a partner was essential for navigating the technical complexity of drone programming tasks. Cognitive peer support most frequently took the form of collaborative debugging, mutual error checking, and joint problem-solving. Partners worked together to identify bugs, test alternative solutions, and reason through programming logic, often catching errors that one individual might have overlooked. As one participant explained, *"We just, like, assisted each other anywhere… like saw bugs or something."*. Another student highlighted the value of mutual monitoring, noting, *"Your if statements were wrong and there's like a little variable, he would point that out."*. These interactions suggest that peer support functioned as a form of cognitive scaffolding that enabled students to complete technically demanding tasks. In addition to cognitive support, students described emotional and social dimensions of peer support that reduced isolation and increased confidence. Several participants noted that simply not working alone made challenging tasks more manageable, with one student stating, *"It was really nice to have someone to work with, like not being by yourself."* Trust and rapport between partners further facilitated collaboration, as reflected in comments such as, *"Thankfully, me and my partner had really great synergy."*.

Task Coordination and Sustained Collaboration

Peer support structured how work through projects was organized and sustained over time. Students described dividing labor based on efficiency, strengths, or time constraints, often assigning one partner to focus on coding while the other handled documentation or reporting. For example, one participant shared, *"I was usually, like, doing the code… and then she was doing more like the report."* In some cases, roles were flexible and shifted as project needs changed, illustrating adaptive collaboration: *"We'd sometimes completely just interchange the roles."*.

Collaboration occurred both during in-person lab sessions and outside of class through asynchronous communication tools. While many students reported completing most of their work during scheduled lab time, others relied on platforms such as Discord or phone calls to coordinate progress outside class, indicating that peer support extended beyond the classroom.

Higher-Order Thinking Through Peer Support

Peer interactions were closely tied to the development of higher-order thinking skills. Students described engaging in iterative trial-and-error processes, diagnosing system-level issues, and reasoning through whether errors stemmed from software, firmware, or hardware. One participant explained, *"We would just keep stacking our work… until our code successfully ran,"* while another reflected on analytical troubleshooting, asking, *"Is it hardware issues and software issue?".* Students also reported consulting documentation together to refine their understanding, reinforcing learning through explanation and shared sense-making. As one student noted, *"I feel like I learned better that way too."*

Motivation and Persistence Through Peer Support

Focus group data further revealed that peer support played a critical role in sustaining motivation and persistence during challenging lab sessions. Students frequently described pushing through frustration and continuing to work until their programs functioned correctly, often attributing this persistence to having a partner. One participant emphasized, *"Just to not, like, give up until it's working,"* while another reflected on the emotional reward of success: *"You just have… satisfaction when you see the work that you put in the code."* These accounts suggest that peer support contributed to emotional resilience and sustained engagement in complex technical tasks.

Challenges Reported

Although students encountered challenges such as scheduling conflicts, uneven participation, and technical setup issues, peer support often mitigated these constraints rather than exacerbating them. Partners adapted by sharing work asynchronously or compensating for absences, and students reported relatively few interpersonal conflicts. Additionally, learning extended beyond assigned pairs through observation and informal exchanges across groups. Seeing other teams succeed helped normalize struggle and reinforced confidence, as one student explained, *"Seeing another group figure it out… I know I can do that now.".* Another participant noted that solutions often spread organically across the classroom: *"The solution to that error would kind of diffuse through the classroom."*.

Overall, the focus group findings indicated that peer support in this FL-PBL cyber-aerial computing course was not merely social, but deeply embedded in how students reasoned, collaborated, persisted, and ultimately completed complex and ethically situated drone programming projects.

Discussion

The findings of the study suggest that peer support functions as a central mechanism for learning extending beyond social interaction to play structural, cognitive, and motivational roles. Students' focus group interview responses indicate that peer support scaffolded complex problem-solving through collaborative debugging, joint reasoning, and system-level diagnosis, supporting higher-order thinking skills such as analysis, synthesis, and problem-solving during drone-centered programming tasks. Also, peer support structured how work was organized and sustained, enabling students to divide labor, adapt roles, and maintain progress across in-class and out-of-class learning contexts. Importantly, peer interactions also fostered motivation and persistence helping students push through technical frustration and remain engaged until projects were successfully completed. Even when challenges such as scheduling conflicts or technical constraints arose, peer support often alleviated these barriers rather than exacerbating them.

Although the primary findings focused on cognitive and collaborative dimensions of peer support, the course context also emphasized ethical considerations related to privacy and security in drone technologies. While students did not explicitly foreground ethical reasoning in their focus group responses, the collaborative structures appeared to create a shared space for discussing challenges and decision-making processes. Future iterations of the study will more explicitly examine how peer interactions may support ethical reasoning and responsible decision-making in technology-rich engineering contexts.

Taken together, these findings provide a clear response to the research question. Peer support in this flipped project-based learning environment functioned as (1) a cognitive scaffold, enabling students to engage in collaborative debugging, joint reasoning, and system-level analysis; (2) an organizational structure, supporting task coordination, role distribution, and sustained collaboration across in-class and out-of-class contexts; and (3) a motivational driver, fostering persistence, emotional support, and continued engagement in the face of technical challenges. Through these interconnected roles, it is evident that peer support directly contributed to students' ability to successfully complete complex drone-based programming tasks while engaging in higher-order thinking processes.

Implications for Future Research

As a WIP study situated within a DBR framework, this study points to several directions for future inquiry. From a design perspective, the findings suggest that structuring peer interactions through collaborative debugging, flexible role distribution, and sustained peer dialogue may enhance students' higher-order thinking and persistence in technology-rich engineering learning environments. These preliminary design insights will inform subsequent iterations of the course by guiding the refinement of peer support structures. First, subsequent iterations of this study will incorporate full analysis of survey data to triangulate focus group interview findings and examine relationships between peer support, higher-order thinking, and learning outcomes. Additional research may also examine how peer interactions could support ethical reasoning and decision-making in technology-rich engineering education contexts.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small (N = 17) and drawn from a single course at one institution, which may limit the generalizability of the results. Second, the findings primarily rely on focus group interviews and self-reported survey data, which may be subject to bias in participants' perceptions and recollections. Finally, as this is a work-in-progress study, the survey data analysis is still ongoing, and the current findings represent preliminary insights. Future research will incorporate full mixed-methods analysis to provide a more comprehensive understanding of the relationship between peer support, higher-order thinking, and learning outcomes.

References

[1] H. J. Gong, H. Park, and T. C. Hagood, “Peer learning in STEM: A qualitative study of a student-oriented active learning intervention program,” *Interactive Learning Environments*, vol. 31, no. 4, pp. 1922–1932, 2020.

[2] K. Howells, *The Future of Education and Skills: Education 2030 – The Future We Want*. Paris, France: OECD Publishing, 2018.

[3] M. Inda-Caro, M. Viñuela-Hernández, M. Martínez-García, and O. García-Pérez, “The influence of perceived teacher and peer supports and barriers in female Spanish engineering undergraduates,” *School Science and Mathematics*, vol. 122, no. 6, pp. 324–338, 2022.

[4] J. S. Cicek, P. Labossiere, and S. Ingram, “Examining fourth year mechanical engineering student perceptions of graduate attribute competencies: Year three,” in Proc. Canadian Engineering Education Association (CEEA), 2015.

[5] J. G. Tullis and R. L. Goldstone, “Why does peer instruction benefit student learning?” *Cognitive Research: Principles and Implications*, vol. 5, no. 1, Art. no. 15, 2020.

[6] F. Cust, “Increasing confidence of first-year student nurses with peer mentoring,” Nursing Times, vol. 114, no. 10, pp. 51–53, 2018.

[7] F. Cust and K. Guest, “Peer support for undergraduate children’s nursing students,” Journal of Nursing Education and Practice, vol. 10, no. 4, pp. 21–25, 2020.

[8] C. C. Dosoftei and L. Alexa, “Students’ perception of peer teaching in engineering education: A mixed-method case study,” *Humanities and Social Sciences Communications*, vol. 11, Art. no. 793, 2024.

[9] R. Lima, P. Andersson, and E. Saalman, “Active learning in engineering education: A (re)introduction,” *European Journal of Engineering Education*, vol. 42, no. 1, pp. 1–4, 2017.

[10] L. Jamieson and J. Lohman, *Innovation with Impact: Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*. Washington, DC, USA: ASEE, 2012.

[11] S. Hartikainen, H. Rintala, L. Pylväs, and P. Nokelainen, “The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education,” *Education Sciences*, vol. 9, no. 4, Art. no. 276, 2019.

[12] J. Tomkin, S. Beilstein, J. Morphew, and G. Herman, “Evidence that communities of practice are associated with active learning in large STEM lectures,” *International Journal of STEM Education*, vol. 6, no. 1, Art. no. 22, 2019.

[13] G. Perez *et al.*, “The role of peer interaction and language resources in informal engineering learning environments: The case for learning through biking,” in *Proc. ASEE Annual Conf. & Exposition*, Montreal, QC, Canada, June 2025, doi: 10.18260/1-2--57262.

[14] D. Boud, R. Cohen, and J. Sampson, “Peer learning and assessment,” *Assessment & Evaluation in Higher Education*, vol. 24, no. 4, pp. 413–426, 1999.

[15] S. Clarence, “Peer tutors as learning and teaching partners: A cumulative approach to building peer tutoring capacity in higher education,” *Critical Studies in Teaching and Learning*, vol. 4, no. 1, pp. 39–54, 2016.

[16] Y. Lin and A. Y. Hsu, “Peer mentoring among doctoral students of science and engineering in Taiwan,” *Asia Pacific Education Review*, vol. 13, no. 4, pp. 563–572, 2012.

[17] R. Pillay and M. Laeequddin, “Peer teaching: A pedagogic method for higher education,” *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 1, pp. 2907–2913, 2019.

Appendix

Sample Focus Group Interview Questions

1. How would you describe your learning experience in this course?
2. How did you work with your peers during the course (or lab projects)? How often did you communicate with your partner?
3. Did your collaboration happen mostly during class time, outside of class, or both? How did you and your partner divide/coordinate/solve tasks when working as a pair?
4. Were there any challenges with peer work?
5. Did other groups affect your learning or not?

Sample Mid-Course Survey Question

1. How has the lab experience in this course been (e.g., experiments, projects, pair works, TA supports, extra labs)?

Sample Post-Course Survey Questions

A 5-point Likert scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree):

1. When we work together in pairs, we tried to make sure that each peer learned the assigned task.
2. When we work together in pairs, our job was not done until both of us has completed the task.
3. When we work together in pairs, we could not complete a task until both of us contribute.
4. When we work together in pairs, each peer's ideas were needed to be successful.
5. Other groups' work influenced my learning during the lab projects.

Check all that apply:

6. Which best represents how you and your peers worked together?
   - ☐ No collaboration
   - ☐ We asked and answered short questions to each other.
   - ☐ We divided tasks and shared results with each other.
   - ☐ We worked individually on projects but helped each other.
   - ☐ We worked jointly on the same tasks.