Work in Progress: An observation study of the PEER-led, Student Instructed, STudy group (PEERSIST) model in thermodynamics

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Abstract
The PEERSIST (Peer-led, Student Instructed STudy group) model promotes academic achievement through peer dialogue, in which disciplinary knowledge is socially co-constructed and refined over successive sessions. The study presents and utilizes an observation protocol to evaluate the implementation of peer learning in a mezzanine-level thermodynamics course at a large southwestern public university. The observation protocol was used to measure and compare the student interactions in two types of recitation sections, one of which used Peer-Led Study Groups (PLSGs) and the other of which followed a traditional TA-led format, to help demonstrate that student interactions were the main source of learning in the PLSG sections. The results showed that student interactions occurred at a significantly higher rate in the PLSG sections than in the TA-led sections. The study also analyzed peer interactions by incoming course preparedness in the PLSG sections and found a non-significant relationship between each group's mean pre-course grade point average (GPA) and number of peer interactions.

Introduction

This work-in-progress paper presents results from the PEER-led, Student Instructed, STudy group (PEERSIST) model in thermodynamics at a large, public university in the southwestern United States. Thermodynamics is part of a set of challenging mezzanine-level engineering fundamentals courses that are less commonly investigated than first or fourth-year engineering design courses [1]. PEERSIST seeks to improve student outcomes in thermodynamics by replacing the passive, teaching assistant (TA) led learning that happens in a traditional recitation session with Peer-Led Study Groups (PLSGs) utilizing Treisman's model of peer learning. Treisman's model emphasizes small-group collaboration on the solution of difficult problems [2], [3]. In the PEERSIST model, thermodynamics students work on problems in groups of four to five, as compared to a traditional recitation section size of 25.

The project team initially piloted the PEERSIST model in Spring 2020 as an additional, voluntary hour of collaborative student problem-solving outside of students' regularly scheduled course time. The pilot continued virtually over four semesters during the COVID-19 pandemic. Students in the pilot demonstrated higher achievement on assessments, increased confidence in course content mastery, and greater persistence in completing final course deliverables than students in the course with similar characteristics (e.g., similar exam 1 scores, etc.). The PEERSIST study has since continued with a focus on scaling up the original pilot to in-person instruction. The original design has been strengthened by incorporating the intervention directly into the thermodynamics course. Students now enroll in either a PLSG or traditional TA-led recitation section. Both section types have equal instruction time and numbers of students,

allowing the project team to assess how the presence or absence of peer interaction affects students' engineering self-efficacy, identity formation, and degree persistence. The scaled-up study is two years in duration, totaling four semesters. The study is currently in its third semester as of Spring 2023.

As part of the ongoing study, this paper seeks to test the hypothesis that the PLSG method encourages greater peer interaction than the traditional recitation method, as intended. An observation protocol was developed to quantify interactions between students and between students and the facilitator (i.e., TA). The protocol was applied to both the PLSG and traditional TA-led recitation sections, and the data collected from the two settings are compared in this paper. Specifically, the protocol was used to investigate the following research questions:

1) To what extent does the frequency and nature of student interactions vary between the PLSG and traditional TA-led recitation sections?
2) How do facilitator interactions affect student interactions within PLSGs?
3) To what extent does students' pre-course preparedness affect the frequency of student interactions and/or facilitator interactions in PLSGs?

Literature Review

The PEERSIST model builds upon an intervention developed by Treisman and colleagues based on observations in similar gateway courses [2]–[6]. Treisman observed that Asian students had significantly less difficulty in an introductory calculus course than non-Asian students, which he attributed to their study habits, specifically, studying in groups and forming learning communities around the course material [2]. He implemented similar collaborative learning methods in mathematics workshops that engaged mostly African American and Latino students in group interaction and discussion to drive student learning, finding significantly improved student outcomes because of their participation [2]–[4].

The broader literature supporting the PEERSIST model, a form of cooperative learning, is robust [2], [7]–[11]. A meta-analysis of 305 studies found that cooperative learning promotes greater learning gains among college students than competing with others (effect size=0.68) or working alone (effect size=0.55), irrespective of students' gender, ethnicity, cultural background, language, social class, or ability [9]. Another study found that students who participate in cooperative learning have demonstrably higher exam scores compared to students who do not [10], [12]. Collectively, these studies indicate that small-group peer interactions can have a significant impact on student learning. This paper extends the existing research by quantifying and comparing just how much peer interaction occurs in collaborative learning relative to more traditional methods of instruction. Findings from this work will enable the project team to correlate students' level of peer interaction to other important variables in this study, including their engineering self-efficacy, identity formation, and degree persistence.

Experimental Design

Observation data were collected in Fall 2022. The course consisted of three classes, each with 100 students. Students signed up for recitation sections through the course catalog. These sections were randomly assigned to the control (traditional TA-led recitation) or the treatment (PLSG-based recitation) so that there were equal numbers of each. There were six TA-led

recitation type sections and six PLSG-based recitation type sections in Fall 2022. Each recitation section of 25 students met weekly starting at the beginning of the semester for 50 minutes per session and a total of 16 sessions. During each session, students were given two to three problems selected by the course instructors to solve. Students in both section types were graded similarly, with 50% of their total score related to whether they attended the recitation and the other 50% related to whether they participated in the session. Weekly training and development were held separately for the facilitators (i.e., TAs) leading the PLSG and TA-led sections.

Students in each PLSG section were placed into groups of peers with similar pre-course preparedness, as determined by their grade point average (GPA) at the start of the semester. Each group contained four to five students, for a total of six groups per section. Three facilitators were present in each section and were assigned to help a maximum of two groups in that section. Each group was given two paper copies of the problems sets and worked together to solve the problems on whiteboards to encourage collaboration.

Each TA-led recitation section consisted of 25 students and a single TA. The sections followed one of two formats based on the preferences of the assigned course faculty, none of whom were involved in the study. The first format was purely instruction, meaning the TA solved the entirety of the problem set on the whiteboard for students; this format is stereotypical of many recitations taught at the institution. The other format resembled a "study hall," where students primarily worked on problems individually for the first 30 minutes, and the TA presented solutions to the problem during the last 20 minutes. The primary mode of interaction for both formats was students asking questions to the TA. Both forms of TA-led recitation differed from the PLSG-based recitations because they did not encourage interaction between students.

Table 1 shows the observation protocol used to quantify student interactions. The protocol was designed to track and compare peer interactions in the PLSG and TA-led recitation sections. Observations were made in eight-minute periods by a member of the research team; within the PLSG sections, each eight-minute period focused on a different group, with each group being observed multiple times. Facilitator interactions were observed in both section types using the criteria listed in Table 2 as well.

Table 1. Observation protocol for student interactions developed for this study [13]

Observation category	Description
Student makes a suggestion related to solving a problem.	Student contributes a statement or verbal contribution related to solving the problem.
Student asks a question to peers.	Student asks a question regarding course content related to solving the problem.
Student asks facilitator a question and/or for help.	Student asks a question or makes a comment directed to the facilitator.

Table 2. Observation protocol for facilitator interactions developed for this study [13]

Observation	Description
Facilitator explains course-related concepts or formulae.	Facilitator explains course-related content, requiring more than a brief one sentence hint.

Facilitator gives brief hints for solving a course-related problem.	Facilitator explains course-related content, requiring only a single sentence or hint.
Facilitator intervenes too soon or too often*	Facilitator intervenes too soon and did not let students discuss problem solving skills.
Facilitator allows the group to struggle for too long without intervening*	Facilitator does not step in with help for solving a course-related problem when the group is stuck.

*=Applicable to PLSG-based sections only.

Data Analysis and Results

Student and facilitator interactions in PLSG vs. TA-led recitations

Figure 1A compares the number of student interactions with the number of facilitator (i.e., TA) interactions over each eight-minute observation period. Student interactions encompass all observed interactions initiated by a student, including making suggestions for how to solve a problem, asking each other questions, discussing non-course related content, and asking the facilitators questions and/or for help. Facilitator interactions encompass all observed interactions initiated by the facilitator (i.e., TA), including providing unsolicited hints to students, confirming that students were solving a problem correctly, and any other interruption provided by the facilitator to the students while the students worked on the problems.

Figure 1A shows that students in the PLSG sections demonstrated far more peer interactions than students in both the study hall and lecture-style TA-led recitation sections. An ANOVA analysis comparing the number of student interactions between the three conditions, and the PLSGs were found to produce significantly more student interactions than either of the TA-led recitation formats ($p<.001$). Few student interactions were observed during the lecture-style recitation sections, with most observation periods consisting of the TA solving problems at the whiteboard.

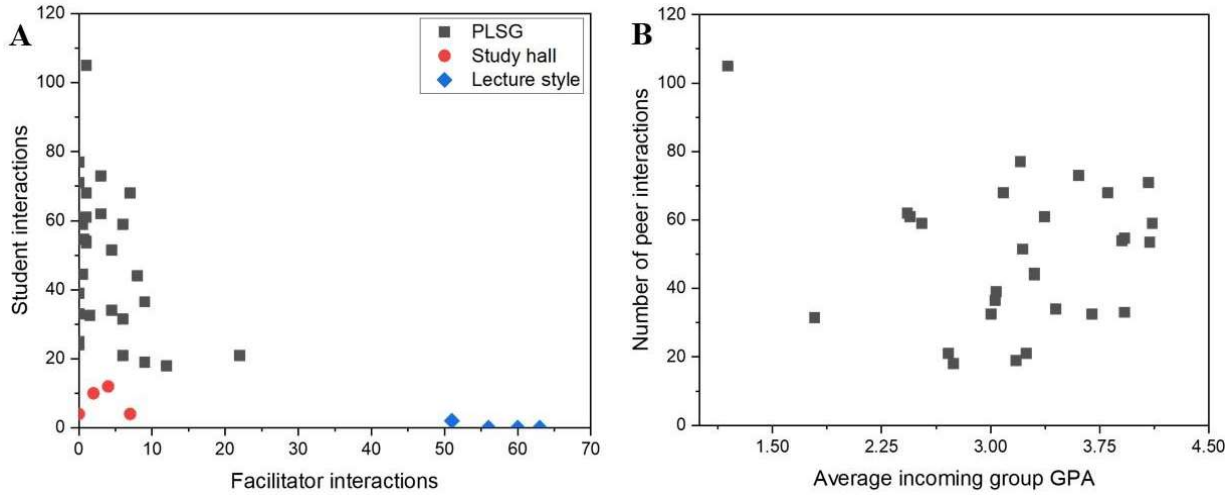

Fig. 1. (A) compares the number of student interactions with the number of facilitator interactions by condition, with each data point representing an eight-minute observation period. (B) shows the number of PLSG student interactions with peers as a function of group-average pre-course GPA, with each data point representing an eight-minute observation period.

Relationship between facilitator and student interactions within PLSGs

Figure 1A additionally shows that the number of student interactions were generally much hihger than the number of facilitator interactions in the PLSG sections. Many PLSG groups worked the problems uninterrupted by the facilitator (i.e., the number of facilitator interactions equaled zero). However, a few outliers corresponding to high levels of both student and facilitator interactions were also present. Correlation analysis revealed that the number of student interactions in an eight-minute observation period was negatively correlated (b=-1.97, p=.003) with the number of facilitator interactions during that same period. This result suggests that too much facilitator intervention has the potential to dampen student interactions in PLSGs.

Effect of incoming course preparedness on PLSG student interactions with peers
The study also examined the effect of incoming course preparedness on PLSG student interactions specifically with their peers. Figure 1B illustrates the number of PLSG student interactions with peers as a function of each PLSG's average pre-course grade point average (GPA). The data are skewed towards mostly higher GPAs, with only seven observed groups having an average GPA below 3.0 on a 4.0 scale. Correlation analysis revealed no significant relationship between the number of student interactions with peers and incoming course preparedness, even after removing a notable outlier corresponding to high peer interaction and low average pre-course GPA (p=.17). The data indicate that the group's average pre-course GPA does not affect students' ability to interact with each other.

Discussion and Future Work
The observation protocol described in this work provided a method for comparing levels of student and facilitator interactions between PLSG and TA-led recitation sections of a thermodynamics course. The data obtained using this protocol confirmed that far greater student interactions occurred in the PLSG sections than in either type of TA-led section (i.e., study hall or lecture style). This result provides evidence that students in collaborative learning environments interact more than students in non-collaborative learning environments. It also suggests that the PLSG intervention based on Treisman's model has been effective and implemented as intended, at least insofar as the method has promoted greater peer interaction. This finding is critical for the current ongoing study which seeks to tie student interactions in the PLSGs to increased self-efficacy, identity, and degree persistence, particularly among transfer students and students historically underserved in engineering (e.g., women, students of color). Future work will further extend the application of this protocol to link engineering student participation in cooperative learning to demographic and exam data as well.

Results from this study also support that PLSGs create an active learning environment that encourages student exploration of the material with minimal facilitator intervention. Students were placed in groups of near peers based on their incoming GPA to the course. Although there were some concerns that GPA may affect the group's ability to interact and solve problems, potentially harming students and resulting in inequitable instruction, the data demonstrated no significant effect on incoming student preparedness on student interaction with peers, alleviating these concerns from the study. Further, greater facilitator interaction was found to have diminishing effects on student interactions, suggesting too much facilitator intervention may be harmful. Information on how GPA and the facilitator affect group interactions can help guide group placement and better train facilitators in the future.

Lastly, while not part of the protocol, students enrolled in the PLSG sections were observed to ask questions and discuss problems at a higher level than their peers in the traditional TA-led recitation sections. They were also more likely to be observed drawing connections from their real-world experiences to justify their answers to their group without being prompted to. For instance, one problem involved determining the final temperature a sword would reach after being quenched in water; the problem required iteratively guessing the final temperature and then checking if the guess was correct. Multiple PLSGs based their guesses on past experiences of placing hot metal in water and seeing that the water does not boil, prompting them to guess a value below water's boiling point. Conversely, most students in the TA-led recitation sections made a starting guess by averaging the initial temperatures of the water and the sword, which produces a temperature well above water's boiling point and does not accurately represent the thermodynamics of the problem. While both methods eventually converged on the same answer, PLSG students often obtained the answer faster. Future work will expand the protocol to measure these question-asking behaviors for additional comparison between recitation formats.

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References

[1] S. M. Lord and J. C. Chen, "Curriculum Design in the Middle Years," in *Cambridge Handbook of Engineering Education Research*, Cambridge University Press, 2014, pp. 181–200. doi: 10.1017/CBO9781139013451.014.

[2] U. Treisman, "Studying Students Studying Calculus: A Look at the Lives of Minority Mathematics Students in College," *The College Mathematics Journal*, vol. 23, no. 5, p. 362, Nov. 1992, doi: 10.2307/2686410.

[3] M. Garland and U. Treisman, "The Mathematics Workshop Model: An Interview with Uri Treisman," *Journal of Developmental Education*, vol. 16, no. 3, pp. 14–22, 1993, [Online]. Available: http://www.jstor.org.ezproxy1.lib.asu.edu/stable/45406673

[4] E. Hsu, T. J. Murphy, and U. Treisman, "Supporting High Achievement in Introductory Mathematics Courses: What We Have Learned from 30 Years of the Emerging Scholars Program," in *Making the Connection*, The Mathematical Association of America, 2008, pp. 205–220. doi: 10.5948/UPO9780883859759.017.

[5] R. E. Fullilove and P. U. Treisman, "Mathematics Achievement Among African American Undergraduates at the University of California, Berkeley: An Evaluation of the Mathematics Workshop Program," *Source: The Journal of Negro Education*, vol. 59, no. 3, pp. 463–478, 1990, [Online]. Available: https://about.jstor.org/terms

[6] H. Duncan and T. Dick, "Collaborative Workshops and Student Academic Performance in Introductory College Mathematics Courses: A Study of a Treisman Model Math Excel

Program," *Sch Sci Math*, vol. 100, no. 7, pp. 365–373, Nov. 2000, doi: 10.1111/j.1949-8594.2000.tb18178.x.

[7] J. J. Snyder, J. D. Sloane, R. D. P. Dunk, and J. R. Wiles, "Peer-Led Team Learning Helps Minority Students Succeed," *PLoS Biol*, vol. 14, no. 3, p. e1002398, Mar. 2016, doi: 10.1371/journal.pbio.1002398.

[8] S. E. Lewis and J. E. Lewis, "Seeking effectiveness and equity in a large college chemistry course: an HLM investigation of Peer-Led Guided Inquiry," *J Res Sci Teach*, vol. 45, no. 7, pp. 794–811, Sep. 2008, doi: 10.1002/tea.20254.

[9] K. A. Smith, S. D. Sheppard, D. W. Johnson, and R. T. Johnson, "Pedagogies of Engagement: Classroom-Based Practices," *Journal of Engineering Education*, vol. 94, no. 1, pp. 87–101, Jan. 2005, doi: 10.1002/j.2168-9830.2005.tb00831.x.

[10] S. C. Hockings, K. J. DeAngelis, and R. F. Frey, "Peer-Led Team Learning in General Chemistry: Implementation and Evaluation," *J Chem Educ*, vol. 85, no. 7, p. 990, Jul. 2008, doi: 10.1021/ed085p990.

[11] K.A. Smith, R.M. Felder, Cooperative Learning in Engineering Education: The Story of an Ongoing Uphill Climb. In Robyn Gillies, Barbara Millis, and Neil Davidson, eds. Contemporary Global Perspectives on Cooperative Learning. New York: Routledge. 2023.

[12] R. F. Frey, A. Fink, M. J. Cahill, M. A. McDaniel, and E. D. Solomon, "Peer-Led Team Learning in General Chemistry I: Interactions with Identity, Academic Preparation, and a Course-Based Intervention," *J Chem Educ*, vol. 95, no. 12, pp. 2103–2113, Dec. 2018, doi: 10.1021/acs.jchemed.8b00375.

[13] G. Lichtenstein, private communication, Sep. 2023