Teaching and Space: How Instructional Methods and Classroom Layout Shape Cognitive Load and Engagement in Engineering Education

Ms. Seongim Moon, University of Florida

Seongim Moon is a Ph.D. student in Engineering Education at the University of Florida. She holds a master's in Interior Design from UF and previously worked as a designer in South Korea, emphasizing the human experience of the built environment. Her research explores how emerging technologies can enhance learning and human experience by deepening our understanding of cognition, emotion, and engagement within educational and spatial contexts.

Dr. Gloria J Kim, University of Florida

Dr. Gloria Kim is an Assistant Professor of Engineering Education at the University of Florida (UF). She is also an affiliate faculty in UF's Department of Electrical and Computer Engineering. She received her B.S. in chemistry from Seoul National University, M.S. in biomedical engineering from Johns Hopkins University, and Ph.D. in biomedical engineering from Georgia Institute of Technology. As an instructional associate professor, she was awarded several grants from the National Science Foundation (IUSE Level 1, IRES Track 1, I-Corps, and I-Corps for Learning) as principal investigator. She transitioned to tenure track in Fall 2023 to pursue her research interests in convergence in engineering education, global engineering education, and social issues in STEM research and practice. Recently, she has taken on new NSF projects to broaden participation in quantum engineering (IUSE Level 3), research abroad (IRES Track 1), and use-inspired research (Convergence Accelerator Track I). Having grown up in Australia, Canada, Korea, and Germany, she speaks three languages. Leveraging her international connections, she has served in leadership positions in the Korean-American Scientists and Engineers Association (KSEA, Vice President), Korean Society for Engineering Education (KSEE, International Relations Board Member), and the International Federation of Engineering Education Societies (IFEES, Executive Committee Member).

WIP: Teaching and Space:
How Instructional Methods and Classroom Layout
Shape Cognitive Load and Engagement in Engineering Education

Abstract

This study investigates how instructional methods and classroom layouts interactively influence students' cognitive and behavioral engagement in engineering education. Unlike earlier work that primarily focused on spatial design and furniture arrangement, this research compares distinct instructional styles while controlling spatial factors such as screen orientation and seating configuration. Grounded in an introductory circuits course with 174 enrolled students, of whom 161 attended in person, the research evaluates how combinations of teaching approach and physical positioning are associated with student engagement and learning-related experiences. A mixed-method approach integrates live classroom observations with controlled virtual reality (VR) experiments.

In this work-in-progress paper, two sections of an introductory circuits course with different teaching styles and screen configurations were analyzed using the COPUS and BERI protocol. Surveys measuring engagement and perceived cognitive load were conducted. The VR experiment that follows will recreate these conditions in a controlled setting to discern to what extent instructional style and spatial arrangement influence students' classroom experiences. Physiological responses such as heart rate variability (HRV) and pupil dilation with eye-tracking and self-reports will be used to examine attention, cognitive load, and engagement.

Building on earlier studies, this research adds physiological measurements to behavioral and self-reported data, offering a more complete picture of how instructional practices and classroom spatial arrangements jointly influence learning. The findings will offer empirical evidence on the interaction between teaching practices and environmental design in shaping attention, engagement, and learning experiences. By linking physiological signals, observed behaviors, and self-reports to students' learning experiences in real classroom settings, the study aims to equip instructors with insights for managing cognitive load and informs the design of learning spaces that encourage focus and participation.

Introduction and Background

Efforts to improve student engagement and learning experiences have long been central to educational research. As recognition has grown regarding the importance of interaction and active participation during class [1], attention has increasingly extended beyond instructional methods to include the physical classroom environment as a factor influencing learning experiences [2], [3], [4]. In this context, classrooms are no longer viewed as neutral physical backdrops, but as conditions that shape how students participate and interact during instruction.

Within engineering education, a growing body of research has examined how redesigning classroom spaces can promote student engagement and interaction. Prior studies suggest that flexible seating arrangements and reduced physical distance between instructors and students can support the development of learning communities and encourage participation [5], [6]. These findings have provided empirical support for investments in classroom redesign and have reinforced the perceived value of learning spaces in shaping educational experiences.

However, a common feature of much of this prior work is that active learning is often treated as a relatively fixed instructional condition. Research has typically focused on evaluating whether classroom layouts or spatial features support student engagement within an already established teaching approach. As a result, the ways in which classroom space and instructional practices jointly operate have received less direct attention.

In practice, engineering courses are rarely conducted using a single, uniform instructional approach. Even within the same course, instruction may shift between concept explanation, worked examples, individual problem solving, and peer interaction. Under such conditions, it is difficult to assume that a given classroom layout supports learning in the same way across all instructional moments. While certain spatial arrangements may facilitate attention and participation in some instructional contexts, they may also introduce cognitive burden or distraction in others.

From this perspective, the key question is not simply whether classroom space increases engagement, but how classroom layouts function differently depending on how instruction is enacted. This study addresses this question by analyzing how students' engagement and cognitive experiences vary across combinations of instructional practices and classroom layouts in engineering classrooms. Rather than prescribing changes to classroom configurations for different instructional phases, the study seeks to understand how the same space may be experienced and utilized differently depending on instructional strategies.

Accordingly, this study examines an introductory circuits course for electrical engineering majors to explore how the combination of instructional methods and classroom layouts is associated with students' engagement and cognitive load. The goal is not to evaluate the effectiveness of a specific teaching method or classroom design. Instead, using a mixed-methods approach that integrates classroom observation, student surveys, and subsequent controlled virtual reality experiments with physiological measures, this research aims to develop an initial understanding of how instructional and spatial conditions jointly shape students' learning experiences.

Research Questions

This study examines how students' engagement and cognitive load are shaped by the interaction between instructional methods and classroom spatial configurations in an introductory circuits course.

The study is guided by the following research questions (RQs):

RQ1. How do instructor and student behavioral patterns during class differ across instructional method and classroom layouts?

RQ2. To what extent do students' self-reported engagement and perceived cognitive load vary across instructional method and classroom layouts?

RQ3. How do physiological indicators associated with attention and cognitive load differ across instructional method and classroom layouts?

This work-in-progress paper addresses RQ1 and RQ2 through the class observations and student self-reported engagement and perceived cognitive load. RQ3, which focuses on physiological measures of attention and cognitive load, is reserved for subsequent phases of the study.

Methods

Research Design

This study adopts an exploratory mixed-methods research design to examine how instructional methods and classroom layouts are associated with students' engagement and cognitive experiences in an introductory circuits course. Rather than isolating spatial or instructional variables, the study is situated in real classroom settings where teaching practices and physical arrangements naturally co-occur. This design allows the research to document how engagement-related behaviors and student perceptions are observed within authentic instructional contexts.

The study was conducted across two sections (A and B) of the same introductory circuits course (Circuits I) in Fall 2025. A total of 174 students were enrolled in the course; the study sample was restricted to the 161 students attending in person, as the observational component required physical presence in the classroom. Circuits I is primarily taken by Electrical Engineering and Computer Engineering majors, with a small number of students from related disciplines (e.g., physics, mechanical engineering, and aerospace engineering). Both sections convened three times a week for 50 minutes each, offered identical course content, learning objectives, and instructional materials, and were taught by instructors with comparable teaching experience. Despite these similarities, the two sections differed in instructional delivery and classroom configurations, including screen orientation, seating arrangements, and the physical positioning of instructors and students. These differences provided a comparative context for examining how variations in instructional and spatial conditions were reflected in classroom behaviors and student-reported experiences.

Student engagement was examined from a behavioral perspective, focusing on observable classroom behaviors occurring under contrasting instructional and spatial conditions. Engagement was conceptualized not as a single outcome but as a set of observable behaviors shaped by instructional strategy, task demands, and classroom layout. This framing enabled the analysis to describe how engagement-related behaviors appeared across different instructional–spatial configurations within the same course context.

In addition to behavioral observations, student self-reports were collected to contextualize the observed engagement patterns. These measures included perceived engagement and perceived cognitive load, capturing students' subjective cognitive experiences during class sessions. Cognitive load was treated as an experiential construction reported by students, allowing the study to document how students perceived cognitive demands under different instructional and spatial conditions.

As an exploratory study conducted in live classroom environments, this research is designed to identify and describe patterns observed in behavioral engagement and student perceptions, rather than to test causal relationships. The research design reflects the complexity of instructional settings and supports an initial examination of how instructional practices and classroom layouts are jointly reflected in classroom engagement and cognitive experiences.

Data Collection

Data were collected through classroom observations and brief student surveys. Classroom observations were conducted during regularly scheduled class times across three class sessions in

November 2025. During these sessions, there were 59 students present in Section A and 102 students present in Section B.

Two trained observers collected observational data using two established protocols: the Classroom Observation Protocol for Undergraduate STEM (COPUS) and the Behavioral Engagement Related Instruction (BERI) protocol [7], [8]. COPUS was used to systematically record instructor and student behaviors at two-minute intervals, capturing instructional activities and overall classroom dynamics throughout each 50-minute class session. BERI was used concurrently to assess behavioral engagement by tracking a subset of students during class.

In each observation session, ten students were selected and coded at two-minute intervals based on observable behaviors, which were classified as Engagement, Unsure, or Disengagement. To capture multiple perspectives and reduce observer bias, observers were positioned in different areas of the classroom, including the front, back, left, and right sides. Both observation instruments were applied consistently across all observed sessions to ensure comparability of the data.

In addition to observational data, brief student surveys were administered during each observation session. The survey collected self-reported student experiences related to perceived course difficulty, clarity of instruction, and classroom layout, including visibility and spatial comfort. These survey data were used to contextualize and support the interpretation of the behavioral observation findings.

All collected data were anonymized and used solely for research purposes. Access to the data was restricted to the research team, and all materials were securely stored on password-protected devices. Institutional Review Board (IRB) approval is currently in progress.

Results

Classroom Observation Results (COPUS)

COPUS analysis indicated that the two sections (A and B) exhibited different instructional strategies, as reflected in the distribution of instructor and student behaviors. In Section A, instructor behaviors were primarily categorized as guiding (45.47%) and presenting (41.78%), suggesting a relatively balanced instructional flow between concept explanation and individual or small-group student support. In contrast, Section B showed a higher proportion of presenting behaviors (52.81%) and a lower proportion of guiding behaviors (36.11%), indicating a more lecture-centered instructional strategy in which concepts and examples were delivered in a step-by-step manner (see Figure 1).

Differences were also observed in student behaviors (see Figure 2). In Section A, the most frequent student behaviors were receiving (55.13%) and classroom working (36.95%), with students transitioning to individual or peer-based problem solving relatively early following conceptual explanations. On average, approximately 25 minutes were devoted to core concept instruction before shifting to activity-based work. In contrast, Section B showed a higher proportion of receiving behaviors (53.99%), followed by classroom working (19.02%) and talking to class (16.78%). In this class, lecture-centered instruction continued for an average of approximately 35.67 minutes before problem-solving activities began.

Behavioral Engagement Patterns (BERI)

BERI analysis indicated the presence of disengagement in both sections, with differences observed in overall levels and distributions across class segments (see Figure 3). For the purposes of this analysis, the overall class period was divided into three equal segments, denoted as early, middle, and late. In Section A, which devoted a relatively larger proportion of time to activity-based instruction, the average disengagement rate was 14.86%, with segment-level values of 18.96% (early), 14.23% (middle), and 11.46% (late). In Section B, where lecture-centered instruction occupied a greater portion of class time, the average disengagement rate was higher at 23.04%, with segment-level values of 22.62% (early), 27.56% (middle), and 19.05% (late).

The lower disengagement observed during the late segment may be partially attributable to students leaving the classroom or changing seats immediately after assignments were distributed, which may have resulted in underestimation of disengagement during this phase.

Student Survey Results

Student survey responses indicated broadly similar perceptions across the two sections. Students in both sections rated course difficulty at a moderate level, with mean values ranging from 3.28 to 3.31 on a 5-point scale (1 = very easy, 5 = very difficult) and reported that the instructor's explanations were relatively high levels of clarity and ease of understanding, with mean scores ranging from 3.82 to 3.89 on a 5-point scale (1 = not clear at all, 5 = extremely clear). Students also indicated low levels of discomfort related to classroom visibility or layout, with mean scores ranging from 2.07 to 2.40 on a 5-point scale (1 = extremely comfortable, 5 = extremely uncomfortable) and reported that the class was helpful for understanding concepts and examples, with mean scores ranging from 3.75 to 3.77 on a 5-point scale (1 = not helpful at all, 5 = extremely helpful).

Figure 1. Differences in student behavior between Sections A and B

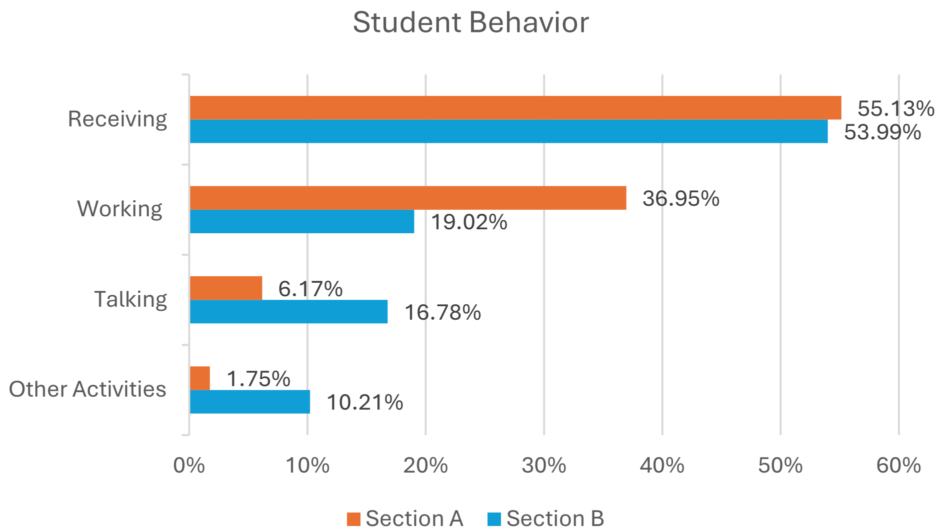


Figure 2. Differences in instructor behavior between Sections A and B

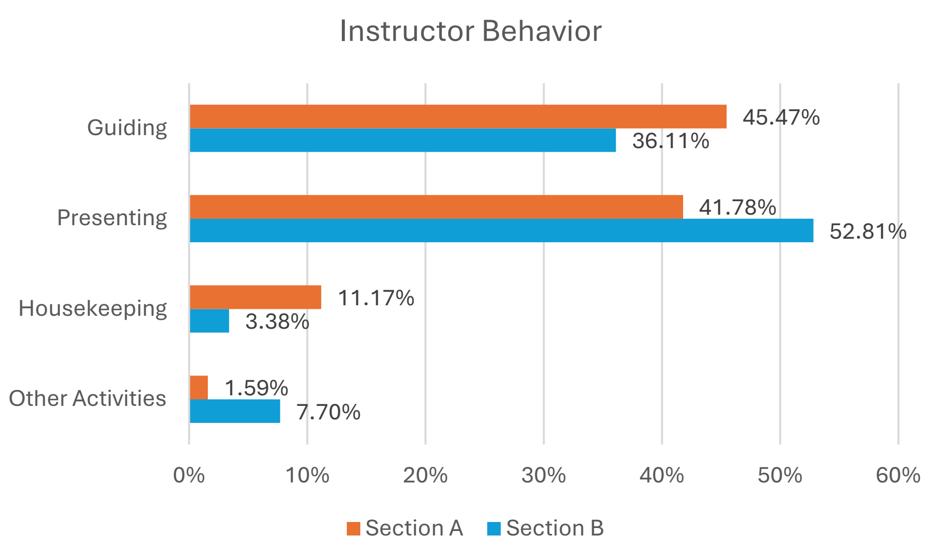
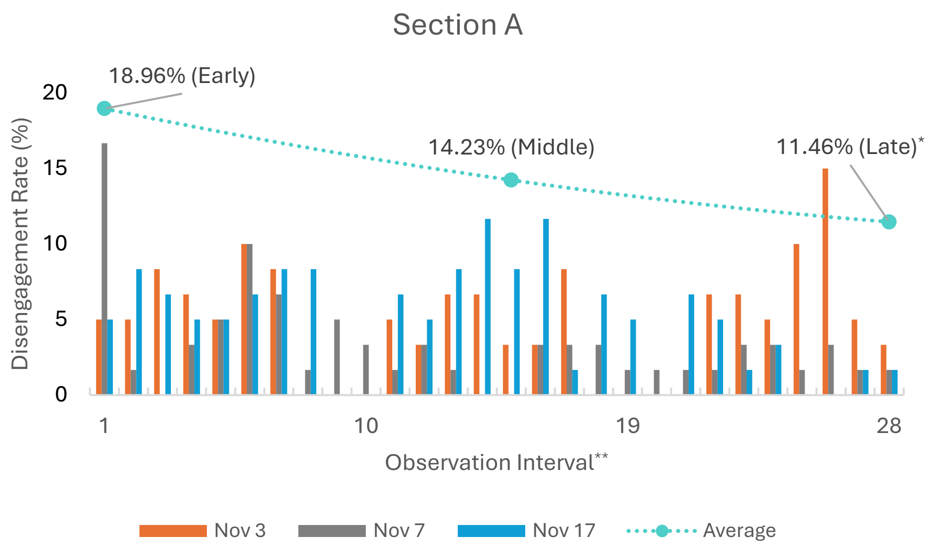
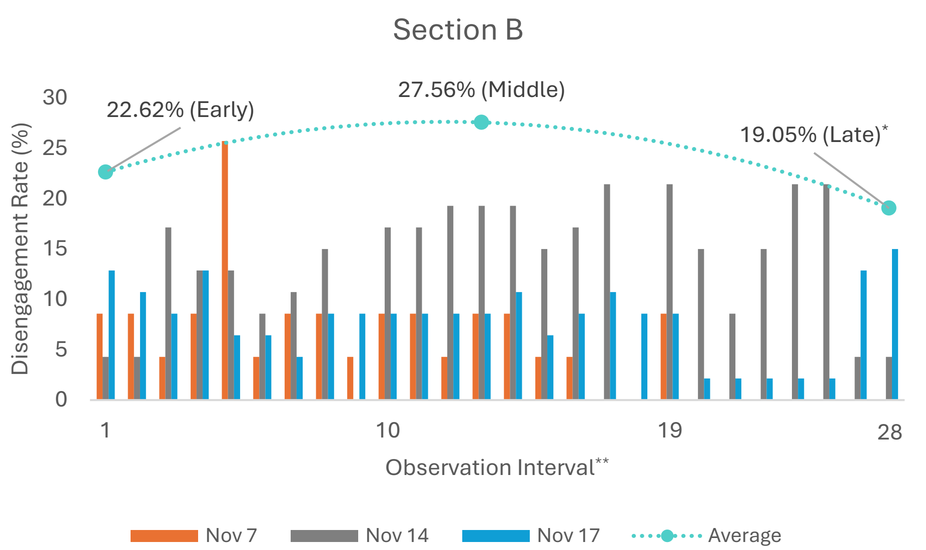


Figure 3. Observed disengagement rates across class time segments for Sections A and B, calculated from systematic observations conducted at 2-minute intervals over a 50-minute class period using a sample of ten students.





* Most students left the classroom.
** Each interval represents 2-minute mark, e.g., interval 1 = 0 - 2 minutes, interval 2 = 2 - 4 minutes, etc.

Discussion

Based on classroom observations and student survey data collected from two introductory circuits class sections, this work-in-progress study documents how observable engagement-related behaviors can differ across sections. COPUS and BERI analyses indicated differences in both instructor behavior categories and student behavior distributions between the two sections, suggesting that classroom activity patterns may vary depending on how instruction is conducted during class.

In contrast, student survey responses indicated generally similar perceptions across the two sections. Students did not report substantial differences in terms of perceived course difficulty, clarity of instruction, classroom visibility, or overall instructional support. This discrepancy suggests that differences observed in behavioral engagement during class may not be fully reflected in students' self-reported perceptions.

Taken together, the divergence between observational and survey findings highlights that relying on a single measurement approach may be insufficient for understanding students' in-class experiences. Behavioral observations capture engagement-related actions as they occur during class, whereas self-report surveys reflect students' retrospective and holistic impressions of the course. The present study contributes by documenting how these two types of data can yield different insights within a live classroom setting.

Conclusion and Future Work

This exploratory study examined how observable engagement-related behaviors and student perceptions appear under different instructional conditions within an introductory circuits course. Classroom observations revealed differences in instructor behavior composition and student behavioral patterns across the two class environments, while student surveys showed largely similar perceptions across sections. These findings indicate that behavioral indicators of engagement observed during class do not necessarily align with students' self-reported experiences.

Rather than evaluating the effectiveness of specific instructional methods or classroom layouts, the contribution of this study lies in its parallel use of behavioral observation and student self-report data to characterize student engagement from multiple perspectives in a live classroom context. By showing that these data sources may capture different aspects of the classroom experience, the study provides a foundation for more nuanced measurement strategies in future research.

This study is based on observations conducted at limited points during the semester, and the findings should therefore be interpreted cautiously with respect to broader generalization across courses or instructional contexts. Additionally, instructional methods and classroom layouts were not treated as isolated variables but were observed as they naturally co-occurred in practice. This was a deliberate design choice consistent with the exploratory aim of documenting classroom phenomena as they occur in real instructional settings.

Future work will extend this study by collecting additional classroom observation and survey data from the same course in a subsequent semester to examine whether similar behavioral and perceptual patterns persist over time. In parallel, a lab-based experiment will be conducted in another semester to investigate these engagement dynamics under more controlled conditions.

Virtual reality (VR) environments will be used to manipulate visual layout and instructional presentation, combined with physiological measures such as eye tracking and heart rate variability (HRV). These methods will enable more precise analysis of students' attention allocation and cognitive load and help clarify the relationship between observed behavioral engagement and students' subjective experiences.

Acknowledgments

The authors would like to thank the two instructors for their support as well as Dr. Alfredo Satriya and Mr. Chandra Galaju for assistance with the observations.

References

[1] R. Talbert and A. Mor-Avi, "A space for learning: An analysis of research on active learning spaces," *Heliyon*, vol. 5, no. 12, p. e02967, Dec. 2019, doi: 10.1016/j.heliyon.2019.e02967.
[2] M. L. Rands and A. M. Gansemer-Topf, "The Room Itself Is Active: How Classroom Design Impacts Student Engagement," *J. Learn. Spaces*, vol. 6, no. 1, pp. 26–33, Nov. 2017.
[3] W. Imms and T. Byers, "Impact of classroom design on teacher pedagogy and student engagement and performance in mathematics," *Learn. Environ. Res.*, vol. 20, no. 1, pp. 139–152, Apr. 2017, doi: 10.1007/s10984-016-9210-0.
[4] M. Odum and K. S. Meaney, "Active learning classroom design and student engagement: An exploratory study," *J. Learn. Spaces*, vol. 10, no. 1, pp. 27–42, Nov. 2021.
[5] P. Shekhar and M. Borrego, "'Not hard to sway': a case study of student engagement in two large engineering classes," *Eur. J. Eng. Educ.*, vol. 43, no. 4, pp. 585–596, Jul. 2018, doi: 10.1080/03043797.2016.1209463.
[6] A. W. Johnson, M. W. Blackburn, M. P. Su, and C. J. Finelli, "How a Flexible Classroom Affords Active Learning in Electrical Engineering," *IEEE Trans. Educ.*, vol. 62, no. 2, pp. 91–98, May 2019, doi: 10.1109/TE.2018.2867447.

[7] S. Wang and P. Apostolellis, “A Student Engagement Evaluation Methodology Inspired from Usability Engineering for Extracting Course Design Requirements,” in *2020 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual On line: ASEE Conferences, Jun. 2020, p. 34056. doi: 10.18260/1-2--34056.
[8] M. K. Smith, F. H. M. Jones, S. L. Gilbert, and C. E. Wieman, “The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices,” *CBE—Life Sci. Educ.*, vol. 12, no. 4, pp. 618–627, Dec. 2013, doi: 10.1187/cbe.13-08-0154.