International Journal of Economic Practices and Theories (IJEPT)
ISSN:2247-7225
Volume 2025 Issue 1

Determinants of Engagement and Outcomes in Flipped Classroom Engineering Education: An Empirical PLS-SEM Analysis

[1]Venkatachalam Ramakrishnan, [2]Dr. N. Manikandan

[1]Department of Business Administration,
Kalasalingam Academy of Research and Education, Krishnankoil.
ORCID: 0009-0005-5088-2843

[2]Department of Business Administration,
Kalasalingam Academy of Research and Education, Krishnankoil.
ORCID: 0000-0003-4147-8863

Abstract

The integration of flipped classroom models in engineering education is reshaping traditional pedagogical paradigms by leveraging technology to foster active learning, critical thinking, and student autonomy. This study investigates how faculty readiness, institutional support, courseware relevance, and technological barriers jointly influence learning engagement and outcomes among engineering students. A survey of 500 undergraduates from multiple engineering colleges forms the empirical foundation for this Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis. Results confirm that faculty readiness and institutional support significantly enhance student engagement, while the relevance of digital courseware serves as an essential catalyst for self-directed learning and meaningful participation. Technological barriers are found to negatively moderate these relationships, underscoring the persistent digital divide's role in shaping student experiences. Learning engagement emerges as a robust mediator, linking input factors with academic outcomes and validating active learning and technology acceptance theories. The study's findings contribute to both theoretical refinement and practical guidance highlighting the need for ongoing investments in faculty development, digital infrastructure, and inclusive teaching resources. Implications suggest that sustainable advances in flipped learning require systemic solutions that align institutional culture, curricular innovation, and equitable technology access. The paper concludes with policy recommendations and a roadmap for future research on digital pedagogy in engineering.

Keywords: Flipped Classroom; Engineering Education; Learning Engagement; Technological Barriers; SEM.

Introduction

The demand for pedagogical innovation in higher education has intensified as rapid advances in digital technologies continue to transform teaching and learning practices worldwide. In response to this shift, the flipped classroom model has emerged as a prominent instructional approach aimed at enhancing active learning, student engagement, and academic achievement, particularly in technical and engineering disciplines. Unlike traditional lecture-centred instruction, the flipped classroom inverts the conventional learning sequence: students first engage with instructional content independently typically through online videos, readings, or learning platforms prior to class, while face-to-face sessions are dedicated to collaborative, applied, and problem-solving activities. Grounded in constructivist and active learning theories, the flipped classroom represents a deliberate transition from passive, instructor-centred pedagogy to student-centred learning experiences. This model empowers learners to actively construct knowledge, apply concepts in authentic contexts, and engage in reflection through peer interaction and instructor feedback. Such an approach is particularly well suited to engineering education, where technical curricula demand deep conceptual understanding, critical thinking, and hands-on application competencies that are best developed through sustained engagement and experiential learning. Empirical evidence strongly supports the effectiveness of flipped classroom approaches in engineering contexts. Meta-analyses by Strelan et al. (2020) and Thai et al. (2017), synthesizing results from thousands of engineering students globally, report moderate to large positive effects on student achievement, skill development, and learner satisfaction. Further, Han et al. (2022) demonstrate that flipped instruction not only enhances academic performance in mechanical engineering courses but also promotes learner autonomy, self-efficacy, and intrinsic motivation key factors for long-term professional competence. Beyond student outcomes, the flipped classroom model offers significant advantages for faculty and institutions. By shifting content delivery to digital platforms, instructors can repurpose classroom time for deeper conceptual discussions, targeted problem-solving and formative assessment, thereby assuming the role of facilitators rather than information transmitters. At the institutional level, flipped learning supports more efficient resource utilization, scalable professional development, and curricular flexibility. Simultaneously, students develop collaborative skills, digital literacy, and self-directed learning capabilities that align closely with contemporary workplace expectations.

Key Drivers and Challenges

Despite the documented benefits of flipped classroom pedagogy, its effective implementation in engineering colleges continues to face persistent structural and pedagogical challenges. Recent literature consistently identifies four interrelated factors as critical determinants of success or failure: faculty readiness, institutional support, courseware relevance, and technological barriers**.** These drivers operate both independently and interactively to shape student engagement and learning outcomes. Faculty readiness defined as the pedagogical, technical, and attitudinal capacity of instructors to design, implement, and evaluate flipped learning environments emerges as the most influential enabling or constraining factor. Empirical evidence suggests that instructors' professional development, prior experience with online or blended teaching, and access to sustained institutional support significantly influence their confidence and effectiveness in flipped classrooms. Zgheib et al. (2023) demonstrate that well-prepared faculty members are more likely to adopt learner-centred strategies that enhance classroom interaction and student achievement, a finding consistent with earlier studies by Martin et al. (2019) and Mane et al. (2025). Conversely, insufficient digital fluency or difficulty in reconceptualising course design often results in superficial implementation and diminished learning gains. Institutional support plays a complementary and equally vital role in sustaining flipped classroom initiatives. Supportive institutional ecosystems characterized by adequate infrastructure, clear academic policies, administrative leadership, and strategic resource allocation create the conditions necessary for pedagogical innovation. Mane et al. (2025) emphasize that investments in collaborative teaching cultures, responsive technical assistance, and structured feedback mechanisms empower both instructors and students throughout the flipped learning cycle. In the absence of such support, even well-designed flipped interventions struggle to achieve scalability and long-term sustainability. Courseware relevance refers to the quality, alignment, and accessibility of digital instructional materials used in the pre-class phase. Effective flipped courseware must bridge the asynchronous synchronous divide by being sufficiently engaging to promote autonomous learning while remaining closely aligned with in-class activities and learning outcomes. High-quality digital content enhances students' preparedness and motivation, whereas poorly designed or misaligned resources undermine engagement, reduce participation, and limit the pedagogical value of in-class interactions. Technological barriers further complicate flipped classroom implementation, particularly in resource-constrained contexts such as many Indian engineering colleges. Limitations related to hardware availability, software access, internet connectivity, and digital literacy can significantly impede student participation and equity. Studies by Betihavas et al. (2016) and Feng et al. (2025) indicate that disparities in technological access disproportionately affect students from rural or marginalized backgrounds, thereby moderating the relationship between flipped instructions and learning outcomes. At the core of the flipped classroom's effectiveness lies learning engagement, encompassing students' cognitive, behavioural, and emotional investment in learning activities. Active learning research (Bishop & Verleger, 2013; Gilboy et al., 2015) establishes engagement as both a key outcome of instructional design and a critical driver of academic success. Students who actively engage with pre-class digital materials and participate in collaborative in-class activities demonstrate higher levels of metacognition, persistence, and knowledge transfer. Recent empirical studies suggest that learning engagement functions as a mediating mechanism through which faculty readiness, institutional support, courseware relevance, and technological context influence learning outcomes. Enhanced support structures and high-quality resources foster greater engagement, which in turn leads to improved academic performance. Lo et al. (2019) report that flipped classrooms outperform traditional instructional approaches even after controlling for prior academic ability and demographic variables a conclusion reinforced by meta-analyses conducted by Akçayır and Akçayır (2018) and Strelan et al. (2020). Despite the growing body of descriptive and comparative research, few studies have systematically examined the combined and mediated effects of these four drivers within a unified analytical framework. To address this gap, Partial Least Squares Structural Equation Modelling (PLS-SEM) is particularly well suited. PLS-SEM enables the simultaneous examination of complex causal relationships, supports mediation and moderation analysis, accommodates measurement error in multi-item constructs, and performs robustly under conditions of non-normal data distribution. Prior research employing PLS-SEM in flipped classroom contexts (Hair et al., 2022; Huang, 2021; Alamri & Al-Rahmi, 2022; Sarstedt et al., 2020) demonstrates its effectiveness in capturing indirect effects and interaction mechanisms, underscoring the importance of contextual validity and representative sampling.

Objectives of the study

1. To analyze the direct and indirect impacts of faculty readiness, institutional support, and courseware relevance on learning engagement and outcomes in flipped engineering classrooms.
2. To evaluate the moderating effect of technological barriers in these relationships, establishing how access and context shape results.

Literature Review

The flipped classroom has significantly transformed teaching and learning practices in higher education, particularly in STEM and engineering disciplines. Unlike traditional lecture-based instruction, flipped pedagogy requires students to engage with digital learning materials prior to class, while classroom time is devoted to collaborative, application-oriented activities and formative feedback. This shift foregrounds active learning as a central mechanism for conceptual understanding and skill development. Meta-analytical evidence consistently supports its effectiveness; for instance, Strelan et al. (2020) report a moderate positive effect on student performance (g = 0.50) across engineering and related disciplines.

Faculty Readiness

Faculty readiness is widely recognized as a primary determinant of successful flipped classroom implementation. Effective adoption depends on instructors' digital competence, pedagogical adaptability, and willingness to redesign courses. Studies emphasize that professional development, mentoring, and institutional encouragement significantly enhances faculty confidence and instructional quality, whereas insufficient training and time constraints contribute to resistance and superficial implementation. Well-prepared faculty consistently demonstrate higher student engagement and improved learning outcomes.

Institutional Support

Institutional support plays a critical enabling role by providing technological infrastructure, policy alignment, and administrative leadership. Research shows that investments in learning management systems, technical support services, and collaborative teaching cultures are essential for sustaining flipped initiatives (Graves & Twigg, 2006; Kerr et al., 2023). Both faculty and students report that institutional scaffolding directly influences flexibility, participation, and instructional effectiveness.

Courseware Relevance

The quality and relevance of digital courseware strongly influence student preparation and engagement. Well-designed, interactive, and context-specific materials enhance motivation and learning transfer, while poorly aligned resources reduce participation and learning gains (Zainuddin & Halili, 2016). Recent reviews identify courseware relevance as a core driver of flipped classroom effectiveness across STEM disciplines (Qi et al., 2024).

Technological Barriers

Technological constraints such as limited device access, poor connectivity, and low digital literacy remain significant challenges, particularly in resource-constrained contexts. These barriers moderate the effectiveness of flipped instruction and disproportionately affect marginalized learners (Betihavas et al., 2016; Feng et al., 2025). Addressing technology inequities through inclusive policies and targeted training is therefore essential for scalable implementation.

Learning Engagement and Outcomes

Learning engagement encompassing behavioural, cognitive, and emotional involvement—is central to flipped classroom success and frequently mediates the relationship between instructional drivers and learning outcomes. Empirical studies show that active engagement enhances self-efficacy, satisfaction, and academic achievement (Galway, 2014; Levesque-Bristol et al., 2019). Engagement is also closely linked to technology adoption constructs, consistent with the Technology Acceptance Model, where perceived usefulness and ease of use drive sustained participation. Learning outcomes in flipped classrooms consistently exceed those of traditional formats, with improvements observed in academic performance, retention, critical thinking, and learner satisfaction (Strelan et al., 2020; Han et al., 2022; Lo & Hew, 2017). These gains are most pronounced when faculty readiness and institutional support are strong, courseware is relevant, and technological barriers are minimized. Despite robust evidence, gaps remain in context-sensitive and integrative research, particularly within Indian engineering education. Scholars call for advanced analytical approaches, mixed-method designs, and institutional-level interventions to better understand the combined effects of pedagogical, technological, and organizational factors on flipped classroom outcomes.

Table 1:

Variable	Explanation	Seminal / Key References
Faculty Readiness	Faculty members' technological proficiency, pedagogical preparedness, and willingness to design, implement, and facilitate flipped classroom instruction.	Hew & Lo (2018); Martin et al. (2019)
Institutional Support	The extent of administrative, infrastructural, policy, and technical support provided by institutions to enable digital and flipped teaching practices.	Mane et al. (2025); Graves & Twigg (2006)
Courseware Relevance	The quality, curricular alignment, interactivity, and accessibility of digital learning materials used in flipped classrooms.	Zainuddin & Halili (2016); Qi et al. (2024)
Technological Barriers	Constraints related to hardware availability, internet connectivity, software access, and digital literacy that hinder effective adoption of flipped classroom models.	Betihavas et al. (2016); Feng et al. (2025)
Learning Engagement	The behavioral, cognitive, and emotional involvement of students in pre-class and in-class learning activities within flipped learning environments.	Strelan et al. (2020); Karabulut-Ilgu et al. (2018)
Learning Outcomes	The behavioral, cognitive, and emotional involvement of students in pre-class and in-class learning activities within flipped learning environments.	Han et al. (2022); O'Flaherty & Phillips (2015)

Methodology

This explanatory study employs a cross-sectional survey with advanced quantitative techniques to evaluate how faculty readiness, institutional support, courseware relevance, and technological barriers affect student learning engagement and outcomes in flipped classroom environments (Hair et al., 2022; Huang et al., 2021; Alamri & Al-Rahmi, 2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) is used for model estimation due to its suitability for predictive, mediation, and moderation analyses with complex multivariate data in educational settings (Hair, Hult, Ringle & Sarstedt, 2022; Sarstedt et al., 2020) A sample of 500 undergraduate engineering students was selected from colleges in Tamil Nadu employing flipped classroom approaches. Inclusion required direct engagement with digital learning experiences. Data collection used a structured questionnaire, after ethics clearance and respondent consent, consistent with survey protocols in recent PLS-SEM educational studies (Huang, 2021; Alamri & Al-Rahmi, 2022; Sage Journals, 2025). Constructs were captured using multi-item Likert scales validated in published flipped classroom and educational technology research.

Construct	Sample Definition	Source
Faculty Readiness	Faculty's skill and motivation for digital pedagogy	Hew & Lo (2018)
Institutional Support	Technical, policy, and administrative resources for digital innovation	ASU (2024)
Courseware Relevance	Alignment and accessibility of digital learning materials	Mintbook (2022)
Technological Barriers	Lack of device access, poor infrastructure, low digital literacy	Betihavas et al. (2016)
Learning Engagement	Student motivation, attention and participation in flipped activities	McLaughlin et al. (2014)
Learning Outcomes	Performance, skill, and knowledge gains from flipped classrooms	Kugler et al. (2019)

Data Analysis:

Descriptive & Reliability Analysis

Descriptive statistics profiled the sample and variable distributions. Reliability was assessed using Cronbach's alpha (>0.7) and Composite Reliability (>0.7); Average Variance Extracted (AVE >0.5) indicated convergent validity (Hair et al., 2022; Alamri & Al-Rahmi, 2022).

Table 2: Reliability and Validity Results

Construct	Cronbach's α	Composite Reliability	AVE
Faculty Readiness	0.87	0.91	0.67
Institutional Support	0.88	0.92	0.7
Courseware Relevance	0.82	0.86	0.63
Technological Barriers	0.85	0.89	0.66
Learning Engagement	0.89	0.93	0.71
Learning Outcomes	0.91	0.94	0.74

Reliability and validity were confirmed per guidelines (Hair et al., 2022; Sarstedt et al., 2020). **Correlation Analysis**

Pearson's r explored variable associations, supporting hypothesis specificity (Field, 2018).

Table 3: Correlation Matrix

	FR	IS	CR	TB	LE
FR	1	0.44	0.48	-0.21	0.51
IS	0.44	1	0.52	-0.19	0.55
CR	0.48	0.52	1	-0.23	0.58

TB	-0.21	-0.19	-0.23	1	-0.31
LE	0.51	0.55	0.58	-0.31	1
LO	0.43	0.48	0.46	-0.17	0.62

All relationships significant at p<.01 except TB-LO (p<.05).

Regression Analysis:

Multiple regressions tested direct effects of independent variables on engagement and outcomes. Moderation was examined through interaction terms (Baron & Kenny, 1986).

Table 4: Regression

Outcome	Predictor(s)	B	SE	T	P
LE	FR, IS, CR, TB	.27*, .33**, .31**, -.18*	0.05	>2.5	<.01
LO	LE, TB	.44**, -.11*	0.07	>2.0	<.01

*Significant at .05; **Significant at .01 level.

ANOVA

One-way ANOVA tested mean differences by demographic subgroup (college, year level).

Table 5: ANOVA Results (Group Differences in Engagement) **Significant difference found**

Group	Mean LE	F- statistic	p-value
College A	4.12		
College B	4.03	3.42	0.02
College C	3.98		

between colleges at p < .05, supporting context effects.

PLS-SEM

Bootstrapping with 5000 samples yielded standardized path coefficients and model fit indices, following guidelines (Hair et al., 2022; Sage Journals, 2025; Sarstedt et al., 2020)

Table 6: PLS-SEM Model Results

Path	B	t	p	95% CI
FR → LE	0.29	6.4	0	.21-.36
IS → LE	0.35	7.1	0	.28-.44
CR → LE	0.32	6.8	0	.24-.41
LE → LO	0.53	8.2	0	.44-.61

TB (mod) → FR, IS, CR → LE	-0.15	4.5	0	-0.31
Model Fit (SRMR)	0.052			

All structural paths significant; moderation by TB confirmed negative impact on enabling factors. Model fit indices met recommended cutoffs (SRMR < .08).

Hypotheses

H1: Faculty readiness positively affects learning engagement (supported).

H2: Institutional support positively affects learning engagement (supported).

H3: Courseware relevance positively affects learning engagement (supported).

H4: Learning engagement positively affects learning outcomes (supported).

H5: Technological barriers negatively moderate effects of faculty readiness, institutional support, and courseware relevance on engagement (supported).

Interpretation of Results

The findings confirm that faculty readiness, institutional support, and courseware relevance are strong predictors of student engagement and learning outcomes in flipped engineering classrooms. Correlation and regression analyses highlight the importance of pedagogical and institutional enablers, while ANOVA reveals significant context-based differences across institutions, underscoring institutional responsibility. PLS-SEM validates the proposed structural relationships and demonstrates that technological barriers significantly moderate these effects, warranting focused policy intervention (Hair et al., 2022; Sarstedt et al., 2020; Huang, 2021). Faculty readiness positively influences engagement by enabling interactive learning, timely feedback, and effective course orchestration, aligning with prior studies (Cho et al., 2021; O'Flaherty & Phillips, 2015). Institutional support emerges as a critical driver, with robust infrastructure and supportive policies fostering innovation and achievement (Arulkumar, 2022; Clark, 2016). Courseware relevance significantly enhances motivation and performance, reinforcing evidence that engaging, aligned digital materials are central to flipped success (Strelan et al., 2020; Lapitan Jr. et al., 2023). Technological barriers, however, dampen these benefits, particularly for disadvantaged learners, confirming the need for equity-focused interventions (Betihavas et al., 2016; Kerr, 2023). Student learning engagement acts as a key mediating variable, linking enabling factors to outcomes such as achievement, self-efficacy, and satisfaction. These results reinforce active learning and constructivist theories and extend the Technology Acceptance Model by highlighting the contextual role of access and digital readiness.

Challenges and Limitations

The study acknowledges resistance to pedagogical change, increased faculty workload, and variability in courseware quality during transition to flipped models. The sample's concentration in urban engineering colleges limits generalizability, indicating the need for validation in rural, polytechnic, and interdisciplinary contexts.

Practical Implications

Institutions should prioritize faculty professional development, robust digital infrastructure, and instructional design support. Investment in high-quality, interactive courseware and targeted strategies to address technological inequities such as device access and digital literacy training is essential. Assessment practices should emphasize engagement, collaboration, and applied learning alongside academic performance.

Theoretical Implications

The study strengthens active learning and technology adoption frameworks by empirically validating engagement as a mediator and technological barriers as a moderator. The use of PLS-SEM advances methodological rigor and encourages future research to incorporate contextual and equity-sensitive perspectives.

Future Directions

Future research should adopt longitudinal and mixed-method designs to examine sustained learning, employability, and skill transfer. Exploring emerging tools such as AR/VR, virtual labs, and learning analytics can further enhance flipped learning. Greater emphasis on digital equity and large-scale, multi-institutional studies particularly in underrepresented contexts is strongly recommended.

Conclusion

This study demonstrates that flipped classroom models, when supported by faculty readiness, institutional commitment, and relevant digital courseware, significantly enhance engagement and learning outcomes in engineering education. Technological barriers remain a critical constraint, highlighting the need for inclusive infrastructure and policy support. By integrating theory-driven analysis with PLS-SEM, the research offers robust evidence that well-implemented flipped pedagogies can transform engineering education into a more active, equitable, and future-ready learning environment.

References

1. Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. Computers & Education, 126, 334–345.
2. Alamri, M. S., & Al-Rahmi, W. M. (2022). PLS-SEM in higher education research. Contemporary Issues in Education Research, 15(2), 54–67.
3. Al-Rahmi, W. M., et al. (2022). Acceptance of a flipped classroom to improve university students' learning outcomes. Sustainability, 14(2), 870.
4. Arulkumar, A. (2022). Impact of the flipped classroom approach in engineering education. Journal of Engineering Education Transformations, 35(4), 47–56.
5. Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research. Journal of Personality and Social Psychology, 51(6), 1173–1182.
6. Betihavas, V., et al. (2016). The flipped classroom in nursing education: A systematic review. Nurse Education Today, 38, 15–21.
7. Bishop, J. L., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. ASEE National Conference Proceedings.

8. Cho, M., et al. (2021). Active learning and faculty readiness. Journal of STEM Education, 22(2), 100–120.
9. Clark, R. (2016). Flipping engineering courses: A school-wide initiative. Advances in Engineering Education, 5(3).
10. Cohen, J., et al. (2013). Applied multiple regression/correlation analysis for the behavioral sciences (3rd ed.). Routledge.
11. Drab-Hudson, C., et al. (2012). Improving student engagement through course redesign. Journal of Higher Education Policy, 74(1), 102–118.
12. Feng, H., et al. (2025). Key factors influencing educational technology adoption in China's colleges. Higher Education, 81(2), 211–230.
13. Field, A. (2018). Discovering statistics using IBM SPSS statistics (5th ed.). Sage.
14. Galvao, V., et al. (2023). Digital barriers in flipped learning: A meta-review. Interactive Technology and Smart Education, 20(3), 184–201.
15. Gilboy, M. B., et al. (2015). Enhancing student engagement using the flipped classroom. Journal of Nutrition Education and Behavior, 47(1), 109–114.
16. Graves, W., & Twigg, C. (2006). Innovations in course redesign. Change: The Magazine of Higher Learning, 38(2), 23–29.
17. Han, F., et al. (2022). The effects of flipped classrooms to improve learning outcomes in higher education. Medicine, 101(27), e29771.
18. Hair, J. F., et al. (2022). A primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.). Sage.
19. Herrmann, A., et al. (2003). Classroom engagement and learning outcomes. Journal of Teaching in Higher Education, 15(2), 171–193.
20. Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves student learning: A meta-analysis. BMC Medical Education, 18(1), 38.
21. Huang, D. (2021). Using PLS-SEM models in higher education research. International Journal of Educational Research, 99, 101527.
22. Hudson, B., et al. (2014). Social learning for student engagement in engineering education. Journal of Engineering Education, 103(2), 251–272.
23. Ji, S., et al. (2021). PLS-SEM modeling for first-year engineering students. Education Research International, Article 38.
24. Karabulut-Ilgu, A., et al. (2018). A systematic review of research on flipped learning in engineering education. British Journal of Educational Technology, 49(3), 398–411.
25. Kerr, M. (2023). Digital inequalities in flipped learning. European Journal of Engineering Education, 48(4), 645–665.
26. Kerr, M., et al. (2023). The flipped classroom in engineering education: A review. Education and Information Technologies, 28(1), 173–193.
27. Kugler, A. J., et al. (2019). Learning outcomes and student preferences with flipped learning. Advances in Physiology Education, 43(3), 353–360.

28. Lapitan, L. D. S., et al. (2023). Enhancing learning with interactive videos in flipped classrooms. Education and Information Technologies, 28(1), 55–73.

29. Levesque-Bristol, C., et al. (2019). Course redesign and autonomy-supportive environments. Journal of the Scholarship of Teaching and Learning, 19(3), 134–150.

30. Lo, C. K., & Hew, K. F. (2017). A critical review of flipped classroom challenges and outcomes. Higher Education, 74(2), 257–278.

31. Mane, M. S., et al. (2025). Teachers' readiness and technology integration in flipped classrooms. International Journal of Multidisciplinary Educational Research, 7(3), 260–290.

32. Martin, F., et al. (2019). Instructor readiness for online teaching. Online Learning, 23(3), 130–146.

33. Mason, G. S., et al. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in engineering. IEEE Transactions on Education, 56(3), 430–435.

34. McLaughlin, J. E., et al. (2014). The flipped classroom: Fostering engagement in health professions education. Academic Medicine, 89(2), 236–243.

35. O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. Internet and Higher Education, 25, 85–95.

36. Prince, M., & Felder, R. (2006). Inductive teaching and learning methods. Journal of Engineering Education, 95(2), 123–138.

37. Qi, Y., et al. (2024). A systematic review of flipped classroom approaches. International Journal of Instruction, 17(4), 601–622.

38. Reeve, J. (2009). Autonomy-supportive teaching. Theory and Research in Education, 7(2), 145–157.

39. Sarstedt, M., Ringle, C. M., & Hair, J. F. (2020). Partial least squares structural equation modeling in educational research. Education and Information Technologies, 25(3), 1647–1667.

40. Strelan, P., et al. (2020). The flipped classroom: A meta-analysis of effects on student performance. Educational Research Review, 30, 100314.

41. Thai, N. T. T., et al. (2017). The flipped classroom: A meta-analysis in engineering education. Education Sciences, 7(1), 32.

42. Tune, J. D., et al. (2013). Flipped classroom model improves graduate student performance. Advances in Physiology Education, 37(4), 316–320.

43. Utami, S. (2024). Flipped classroom approaches in STEM education. Procedia Computer Science, 206, 1157–1168.

44. Yough, M., et al. (2019). Engagement and autonomy-supportive environments in STEM learning. Journal of STEM Education, 20(4), 35–44.

45. Zainuddin, Z., & Halili, S. H. (2016). Flipped classroom research and trends. International Review of Research in Open and Distance Learning, 17(3), 313–340.

46. Zgheib, G., et al. (2023). Faculty perceptions of readiness to teach online. Journal of Online Learning Research, 9(1), 67–84.