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Classroom Implementation Matters: How Diverse Teaching and Learning Strategies Impact First-Year Engineering Students' Learning Efforts?

Nur Shahira Samsuri^a, Syed Ahmad Helmi Syed Hassan^b, Fatin Aliah Phang Abdullah^a, and
Khairiyah Mohd-Yusof^b

Universiti Teknologi Malaysia, Johor Malaysia^a, Purdue University, West Lafayette, United States^b

Corresponding Author's Email: khairiya@purdue.edu

ABSTRACT

BACKGROUND & CONTEXT

First-year engineering students need to develop both adequate technical knowledge and sustained learning effort to achieve their academic goals. While learning effort can be influenced by many factors, especially teaching and learning (T&L) strategies, most research focuses on studying the impact on cognitive and affective outcomes rather than students' effort. Engineering faculties have implemented diverse teaching and learning (T&L) strategies to support students during the transition to tertiary levels, leading to the need for an investigation into how these strategies specifically influence students' efforts to learn.

PURPOSE OR GOAL

This research examines how different T&L strategies influence students' learning efforts through a systematic comparison of implementation characteristics in diverse Introduction to Engineering (ITE) classrooms.

APPROACH OR METHODOLOGY

A comparative cross-sectional design examined 113 first-year engineering students across three distinct implementations: Cooperative Problem-Based Learning (CPBL, $n=30$), Project-Based Learning (PjBL, $n=40$), and Traditional Learning (TL, $n=43$). Data were collected using the validated 96-item Goal Orientation Index measuring conative behaviors across twelve subconstructs. Analysis employed ANOVA and Kruskal-Wallis tests with comprehensive effect size calculations to identify significant differences in learning efforts.

OUTCOMES

Significant differences ($p < .05$) emerged in seven of twelve learning effort dimensions with substantial effect sizes ($\eta^2 = .070$ to $.357$). Active learning approaches demonstrated superior performance in problem recognition and evaluation behavior, while diverse T&L strategies and implementation characteristics significantly influenced acting behaviors across all approaches.

CONCLUSIONS

Implementation characteristics such as team configuration, instructor role, problem focus, collaboration duration, and feedback frequency could impact students' learning efforts. The findings demonstrate that structured environments with these features could enhance students' task execution and persistence capabilities, while approaches lacking these features may undermine strategic action and regardless of pedagogical category.

KEYWORDS

Learning efforts, First-year experience, Teaching and learning strategies, Conative.

Introduction

First-year engineering students enter a challenging academic environment that requires more than technical knowledge acquisition, demanding the development of sustained learning effort to navigate complex educational demands and achieve long-term success (Bowman, 2017). Learning effort represents the observable energy and persistence students invest in educational activities, reflecting their underlying motivation to pursue academic goals (Van Gog et al., 2020). Engineering workplaces now demand professionals who demonstrate sustained effort, strategic thinking, and adaptability when facing complex problems (Murray et al., 2022; Hassan et al., 2022; Mainga et al., 2022), yet research indicates that students often possess adequate knowledge but struggle to maintain the sustained effort necessary for academic and professional achievement (Ko et al., 2017; Hwang et al., 2016). The first-year period proves especially critical because it establishes fundamental learning patterns that influence students' entire academic trajectory, affecting their persistence in engineering programs and eventual professional development (Willems et al., 2021).

In response to these challenges, many higher-education institutions have developed guidance and support initiatives (Willems et al., 2021) by implementing Introduction to Engineering (ITE) courses to facilitate first-year academic transition at the university and prepare students for academic and professional demands. Various teaching and learning strategies implemented include team-based learning (Adams et al., 2015), problem-based learning (Taajamaa et al., 2014), project-based methodologies, and learner-centered approaches (Frey and Banow, 2020). However, research reveals mixed outcomes regarding these strategies' effectiveness on student engagement and academic performance (Calabrese, 2023; Borda et al., 2020). Furthermore, studies indicate that the implementation quality of student-centered practices often falls short of theoretical expectations, with faculty understanding of pedagogical theory not always translating into effective classroom practice (Borda et al., 2020; Dogani, 2023). This implementation gap creates uncertainty about how different teaching approaches influence students' learning effort in real classroom settings, particularly since limited research focuses on the psychological capabilities that drive sustained learning effort rather than cognitive outcomes alone (Langdon et al., 2019).

This study addresses this gap by investigating how different teaching and learning (T&L) strategies influence first-year engineering students' learning efforts in authentic classroom settings. The research examines three distinct implementations representing different pedagogical approaches to understand their varying impacts on students' capacity for sustained learning effort. This research focuses on understanding how actual classroom implementations create different conditions for developing learning effort capabilities. The research question examines: *How do diverse T&L strategies impact first-year students' learning efforts across planning, acting, and reflecting domains?* Using a comparative cross-sectional design with 113 first-year engineering students, this study provides empirical evidence on how different pedagogical approaches affect the strategic capabilities that manifest as sustained learning effort, which are essential for bridging academic preparation and professional requirements.

Conation as a Theoretical Framework for Understanding Learning Efforts

Conation provides a theoretical underpinning for understanding learning efforts, representing the intentional and determined aspect of mental processes that translates knowledge and motivation into purposeful action (Huitt & Cain, 2018; Snow & Jackson, 1994). Historically recognized as one of the tripartite domains of mind alongside cognition (thinking) and affect (feeling), conation has gained renewed scholarly attention for its unique role in explaining the "striving" component of human behavior (Gerdes & Stromwall, 2008; Reeves, 2006). Conation specifically addresses the will to learn and the volitional control mechanisms that enable students to persist through challenges. The relationship between conation and learning effort is fundamental to understanding student success in engineering education. Conation refers to the mental drive, intention, and will that propel students toward goal achievement, aligned with

learning effort, which represents the observable manifestation of this drive through the actual energy, persistence, and strategic behavior students demonstrate in educational activities (Honicke et al., 2020). Research demonstrates that students with stronger conative capabilities typically exhibit greater learning effort and persistence, particularly when supported by appropriate instructional environments that foster autonomy and self-determination (Han, 2021; Stefanou et al., 2013). This relationship suggests that measuring conative behaviors can provide insights into students' capacity for sustained learning effort, making it a valuable framework for understanding how different teaching approaches could influence students' strategy to learn.

The theoretical foundation for this study draws on Atman's (1987) conative taxonomy, which delineates five progressive stages through which individuals engage with goals to complete tasks: perception, focus, engagement, involvement, and transcendence. This developmental framework explains how students move from initial awareness of learning tasks through increasingly sophisticated levels of goal-directed behavior, ultimately reaching complete absorption and mastery. Complementing this developmental perspective, Atman's (1986) conative cycle as shown in Figure 1, identifies twelve specific goal-directed behaviors organized into three primary constructs: (i) Planning: comprising four subconstructs (recognizing problems, *RP*, setting goals, *SG*, determining purpose, *PU*, organizing, *OR*); (ii) Acting, comprising four subconstructs (selecting strategies, *SS*, Push on, *PO*, Make it Happen, *MH*, Wrap it up, *WU*); and (iii) Reflecting, comprising four subconstructs (Brainstorming, *BR*, assessing risks, *AR*, visualizing success, *ACT*, evaluating outcomes, *Ooo & Ahh*, *OA*). These twelve subconstructs represent distinct learning effort dimensions that collectively capture the strategic approaches students employ to navigate complex learning challenges, providing a structured approach for examining how different teaching and learning strategies influence students' capacity for sustained learning effort.

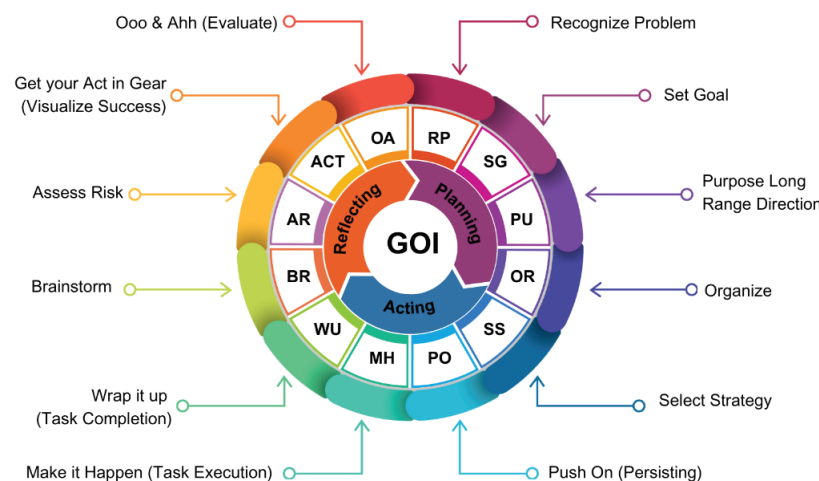


Figure 1: Twelve Goal-Oriented Behavior adopted by Atman's Conative cycle

Teaching and Learning Strategies and Their Potential Impact on Learning Efforts

The effectiveness of teaching and learning strategies in fostering students' learning efforts has emerged as a critical area of investigation in engineering education, with research consistently identifying key environmental factors that influence volitional capabilities. Previous studies demonstrate that teaching strategies that comprise educators' scaffolding could strengthen student self-determination and engagement by compensating for deficits in self-efficacy and autonomy (Tirado-Morueta et al., 2024), while smaller learning environments facilitate personalized approaches and enhanced motivation through improved instructor-student interactions (Sanchez-De Miguel et al., 2023). Additionally, autonomy support by educators

could help to foster ownership and deeper engagement by allowing students to make choices about their learning (Stefanou et al., 2013). Meanwhile, small group participation develops strategic thinking and persistence through collaborative support that enables idea sharing and mutual assistance (Chen, 2011). While these studies demonstrate the influence of specific instructional elements on various aspects of student motivation and engagement, research examining their direct impact on the comprehensive range of conative behaviors that comprise learning efforts remains limited.

Most comparative studies on instructional strategies focus primarily on knowledge acquisition and performance rather than examining the volitional capabilities that enable sustained learning (Struyven et al., 2006; Felder et al., 2000). More concerning, educational research continues to rely on simplified active-versus-passive dichotomies without accounting for implementation factors that significantly influence classroom effectiveness. As Hadgraft and Kolmos (2020) argue, specific elements like feedback frequency, group dynamics, and problem structuring often determine educational impact more than broad pedagogical categories, suggesting that how strategies are implemented may be more critical than which strategies are chosen. This implementation gap is further complicated by evidence that faculty understanding of pedagogical theory does not always translate into effective classroom practice (Borda et al., 2020), creating uncertainty about how different teaching approaches influence students' learning efforts in authentic educational settings.

This study examines three distinct pedagogical implementations to understand their relationship with learning efforts across conative dimensions. Cooperative Problem-Based Learning (CPBL) has been documented as featuring structured problem-solving processes, peer teaching cycles, and continuous feedback systems (Mohd-Yusof et al., 2011), with research demonstrating effectiveness for critical thinking and motivation (Yusof et al., 2016). Project-Based Learning (PjBL) emphasises authentic problems and student autonomy, with studies showing benefits for knowledge application (Frank et al., 2003), though implementation variations in project structure, team composition, and feedback mechanisms create diverse learning environments (Krajcik & Blumenfeld, 2006). Traditional Learning approaches continue to predominate despite documented limitations for developing self-regulation, autonomous learning, and strategic thinking capabilities (Zhang, 2021; Saeheng, 2017). By comparing these three approaches, this research investigates how different classroom implementations influence students' strategic planning (plan), persistent execution (act), and reflective adaptation (reflect) capabilities across the twelve conative subconstructs that comprise learning efforts.

Methodology

This study employed a comparative cross-sectional design to examine how diverse teaching and learning strategy implementations impact first-year engineering students' learning efforts. The research was conducted at a university in Southern Malaysia, examining three distinct course implementations, each implementing unique pedagogical approaches in their Introduction to Engineering (ITE) courses. The study involved 113 first-year engineering students distributed across three programs representing different teaching and learning (T&L) implementation strategies: Program A (30 students, 3-credit CPBL implementation), Program B (40 students, 2-credit PjBL implementation), and Program C (43 students, 1-credit Traditional Learning implementation). Each program enrolled students from various engineering disciplines, with participants representing the full spectrum of first-year engineering students at the institution.

Implementation characteristics were systematically verified through multiple data sources to ensure the validity of the comparative analysis. Document analysis was conducted to collect course information from all three programs, including course syllabi, learning outcomes, assessment methods, weekly schedules, and instructional materials. Additionally, systematic in-class observations were conducted throughout the entire 14-week semester to verify actual implementation practices against documented intentions. The researcher was assigned to

independently observe classroom sessions across all three programs regularly throughout the semester to capture implementation consistency and authentic teaching-learning interactions. The observation protocol focused on instructor-student interaction patterns, team configuration and collaboration dynamics, assessment and feedback delivery methods, student engagement levels, and adherence to stated pedagogical approaches. The three program implementations are compared in Figure 2 below:

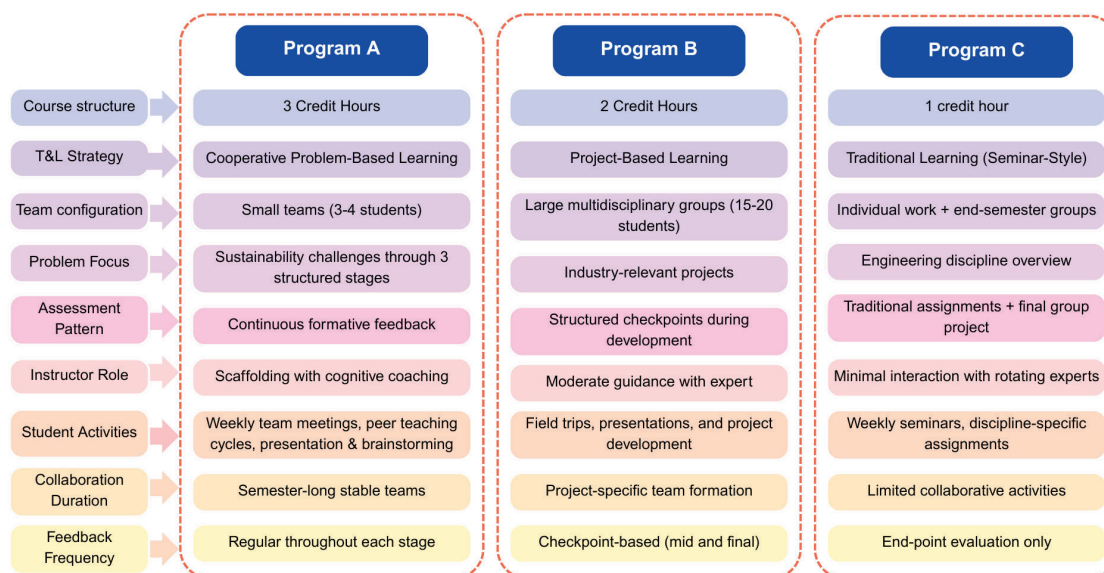


Figure 2: Comparison of Program Implementation Characteristics

Data Collection Procedure

The survey was administered during the final week of the 14-week semester after students had completed their respective course implementations. This timing was selected to ensure that observational data collection throughout the semester could be completed and used to contextualize the implementation environments in which students developed their learning efforts. All participants completed paper-based questionnaires under supervised conditions after providing informed consent. This single-time-point measurement was designed to capture students' learning efforts as developed through their specific T&L implementation experiences. The triangulated approach combining document analysis, systematic classroom observations throughout the semester, and student outcome measurement was implemented to strengthen the validity of implementation descriptions and their use in subsequent comparative analysis.

Data Collection Instrument

Data collection employed the Goal Orientation Index (GOI), a validated 96-item instrument developed by Atman (1986) for measuring students' goal-directed behaviors using a five-point Likert scale ranging from "rarely do" (1) to "almost always" (5). The instrument measures three main constructs of conative behavior that align with learning effort capabilities: Planning (32 items across RP, PU, SG, and OR subconstructs), Acting (32 items across SS, MH, PO, and WU subconstructs), and Reflecting (32 items across BR, AR, ACT, and OA subconstructs), with each subconstruct containing eight items. Reliability analysis confirmed strong internal consistency with Cronbach's alpha values ranging from 0.78 to 0.91 across all constructs, exceeding the recommended threshold of 0.70 (George, 2011). To ensure construct validity and detect acquiescence response bias, negatively worded items were incorporated in the Select Strategy and Push On subconstructs, requiring reverse scoring during analysis, where higher scores indicate poorer performance for these specific dimensions.

Data Analysis

Between-group differences were analyzed using parametric (ANOVA) and non-parametric (Kruskal-Wallis, KW) tests based on data distribution characteristics and homogeneity assumptions. Normality was assessed using Shapiro-Wilk tests, with homogeneity evaluated through Levene's tests. Variables meeting parametric assumptions (PU, OR, RP, SS, BR) were analyzed using ANOVA, while non-normally distributed variables (SG, MH, WU, PO, AR, ACT, OA) were analyzed using Kruskal-Wallis tests. Effect sizes were calculated to determine practical significance alongside statistical significance, following recommendations by Fritz et al. (2012) for comprehensive statistical reporting. Effect size interpretations followed Cohen's (1988) established guidelines: small effect ($\eta^2 \approx 0.01$), medium effect ($\eta^2 \approx 0.06$), and large effect ($\eta^2 \approx 0.14$). These benchmarks have been widely adopted in educational research and provide standardized interpretations of practical significance (Cohen, 1992).

Significant results were followed by appropriate post-hoc analyses—Tukey HSD for ANOVA and Mann-Whitney U tests for Kruskal-Wallis to determine specific between-group differences (Field, 2018). Post-hoc comparisons were interpreted considering both statistical significance (p-values) and practical significance (effect sizes) to provide comprehensive insights into group differences, aligning with current recommendations in statistical literature emphasizing the importance of effect size reporting in multiple comparison scenarios (Fritz et al., 2012). This comprehensive approach enabled a nuanced examination of how different teaching strategies influenced students' learning efforts comparatively across all pedagogical approaches, with particular attention to both the magnitude and practical importance of observed differences.

Results and Findings

The comparative analysis in Table 1 revealed significant differences across seven of twelve learning effort dimensions, demonstrating that diverse T&L implementation strategies create markedly different outcomes in students' effort. These differences manifested distinctively across planning, acting, and reflecting constructs.

Table 1: ANOVA and Kruskal-Wallis Test Results Comparing Learning Efforts Across Programs

Construct		Test Used	Test Statistic	p-value	Effect Size (η^2)	Effect Size Category	Post-hoc Comparisons
Planning	PU	ANOVA	F = 0.321	0.726	0.006	Very Small	No significant differences
	OR	ANOVA	F = 1.216	0.3	0.022	Small	No significant differences
	RP	ANOVA	F = 30.473	0.001**	0.357	Large	A = B > C
	SG	KW	$\chi^2 = 2.605$	0.272	0.005	Very Small	No significant differences
Acting	MH	KW	$\chi^2 = 25.715$	0.001**	0.216	Large	A > B = C
	WU	KW	$\chi^2 = 1.261$	0.532	0	No Effect	No significant differences
	SS	ANOVA	F = 27.211	0.001**	0.331	Large	A > C > B
	PO	KW	$\chi^2 = 23.165$	0.001**	0.192	Large	A > C > B
Reflecting	BR	ANOVA	F = 0.433	0.65	0.008	Very Small	No significant differences
	AR	KW	$\chi^2 = 4.674$	0.097	0.024	Small	No significant differences
	ACT	KW	$\chi^2 = 12.171$	0.002**	0.092	Medium	A = B > C
	OA	KW	$\chi^2 = 9.656$	0.008**	0.07	Medium	A = B > C

**p < 0.01; Effect magnitudes: Minimal ($\eta^2 < .01$), Small ($.01 \leq \eta^2 < .06$), Medium ($.06 \leq \eta^2 < .14$), Large ($\eta^2 \geq .14$)

Note: A = Program A (CPBL), B = Program B (PjBL), C = Program C (TL) PU: Purpose Direction, OR: Organization, RP: Recognize Problem, SG: Set Goal, MH: Make it Happen, WU: Wrap it Up, SS: Select Strategy, PO: Push On, BR: Brainstorming, AR: Assess Risk, ACT: Visualization, OA: Evaluation

Between-Groups Analysis Across T&L Strategies

Within the planning constructs, one-way ANOVA revealed that RP sub-construct emerged as the sole dimension displaying notable variations across T&L strategies, $F(2, 110) = 30.473$, $p < .001$, $\eta^2 = .357$. This large effect indicates that instructional approaches account for 36% of the variability in students' problem identification capabilities. Tukey HSD post-hoc analyses demonstrated that students in both CPBL and PjBL programs significantly outperformed students in traditional instruction (both $p < .001$), while students in CPBL and PjBL groups

showed equivalent performance ($p = .272$). Classroom observations confirmed that students in both active learning environments experienced regular engagement with authentic engineering challenges. Students in CPBL worked through structured sustainability problems, and students in PjBL engaged in multidisciplinary project formulation, whereas students in traditional learning experienced passive seminar-style content delivery with minimal student problem interaction. In contrast, other planning components showed negligible variations with minimal effect sizes, where PU, $F(2, 110) = 0.321$, $p = .726$, $\eta^2 = .006$; OR, $F(2, 110) = 1.216$, $p = .300$, $\eta^2 = .022$; and SG sub-constructs, $\chi^2(2) = 2.605$, $p = .272$, $\eta^2 = .005$. These findings suggest that students' planning capabilities develop uniformly across T&L strategies, likely due to the common introductory nature of all courses.

The acting construct generated the most noticeable findings, with significant outcomes and large effect sizes observed in three of four elements. Kruskal-Wallis analysis for MH sub-constructs demonstrated remarkable variation, $\chi^2(2) = 25.715$, $p < .001$, $\eta^2 = .216$, with students in CPBL achieving notably superior task implementation compared to students in other programs, while students in PjBL and traditional learning showed equivalent performance. Even more significantly, both SS, $F(2, 110) = 27.211$, $p < .001$, $\eta^2 = .331$, and PO sub-constructs, $\chi^2(2) = 23.165$, $p < .001$, $\eta^2 = .192$, exhibited large effects with an unexpected hierarchical pattern where students in CPBL surpassed students in traditional learning, which in turn exceeded students in PjBL. This finding provides evidence that implementation characteristics may influence different aspects of learning effort in varying ways. Classroom observations revealed that students in PjBL worked in excessively large multidisciplinary teams (15 to 20 members) with moderate instructor facilitation, creating diffused responsibility that undermined individual accountability. Similar to Traditional learning instructions, students in PjBL experienced infrequent feedback and inadequate guidance throughout the semester-long project duration. Conversely, students in CPBL worked in small teams, with weekly meetings, peer teaching cycles, and continuous formative feedback throughout structured problem-solving stages, resulting in higher strategic selection and persistence capabilities compared to students in other programs.

The reflection constructs demonstrated diverse outcomes across T&L strategies, with medium effect sizes observed in specific sub-constructs. Both ACT, $\chi^2(2) = 12.171$, $p = .002$, $\eta^2 = .092$, and OA sub-constructs, $\chi^2(2) = 9.656$, $p = .008$, $\eta^2 = .070$, showed that students in CPBL and PjBL achieved a superior performance compared to students in traditional learning. Classroom observations confirmed that students in CPBL engaged in reflection reports and peer evaluations after each problem stage, while students in PjBL participated in reflective journals and progress sharing sessions at certain periods. In contrast, students in traditional learning experienced an instructor-centered seminar format with rotating expert lecturers, providing minimal opportunities for reflection and evaluation sessions.

Discussion

This study investigated how diverse T&L strategy implementations impact first-year engineering students' learning efforts across planning, acting, and reflecting constructs. The comparative analysis across three distinct implementations, which are Cooperative Problem-Based Learning (CPBL), Project-Based Learning (PjBL), and Traditional Learning (TL), revealed significant differences in seven of twelve learning effort dimensions, providing insights into how implementation characteristics influence students' capacity for sustained learning effort.

The enhanced problem recognition (RP) capabilities in the Planning construct demonstrated by both CPBL and PjBL students validate Atman's conative taxonomy emphasis that perception and focus stages require meaningful engagement with genuine challenges to activate goal-directed behavior. This finding supports Stefanou et al.'s (2013) assertion that tasks that are relevant, meaningful, and present realistic challenges create conditions conducive to student engagement in learning. The equivalent performance between CPBL and PjBL suggests that authentic problem exposure universally enhances analytical capabilities

regardless of specific instructional structure, indicating that the presence of real-world engineering challenges serves as the critical factor that influences students to start engaging with the tasks. This aligns with conative theory's emphasis on meaningful problem engagement as foundational for developing strategic learning capabilities.

Furthermore, CPBL students' performance in MH, SS, PO, and WU across all acting dimensions can be theoretically explained through the environmental supports necessary for sustained volitional action. The small team configuration (3-4 members) with continuous accountability and feedback structures directly addresses Chen's (2011) findings that small group participation develops strategic thinking and persistence through collaborative support. This implementation provides the specific environmental conditions that acting behavior requires: individuals' clear accountability, manageable task complexity, and regular feedback cycles. This is supported by Stefanou et al.'s (2013) argument that allowing students to become part of the decision-making process promotes engagement and persistence in learning. The theoretical framework suggests that acting constructs, representing the "striving" component of conation, are particularly dependent on environmental supports that foster individual agency within collaborative structures.

However, the unexpected hierarchical pattern of *CPBL > Traditional Learning > PjBL* in selecting strategy (SS) and push on, persisting (PO), challenges conventional pedagogical assumptions and requires explanation through implementation quality theory. PjBL's large multidisciplinary teams (15-20 members) with infrequent feedback created conditions that compromised individual agency, validating Sanchez-De Miguel et al.'s (2023) research demonstrating that large groups reduce intrinsic motivation levels and limit instructor-student interactions. This finding supports Tirado-Morueta et al.'s (2024) claim that scaffolding can compensate for a deficiency in self-efficacy and autonomy when properly implemented, but inadequate scaffolding in PjBL undermined these benefits. Furthermore, students' performance in traditional learning in acting behaviors may be attributed to its course structure characteristics. The 1-credit-hour course in traditional learning course structure involves minimal collaborative activities and fewer assessment demands compared to PjBL and CPBL, which necessitate extensive project formulation, multiple assignments, and semester-long collaborative requirements. This reduced complexity may have resulted in fewer action-taking demands on students compared to the intensive project-based activities that potentially overwhelmed students in PjBL implementation. The finding demonstrates that implementation characteristics and course design complexity influence learning effort outcomes more than pedagogical labels, as argued by Borda et al. (2020) regarding the gap between pedagogical theory and classroom practice.

The reflective constructs differential outcomes across T&L strategies reveal the varying sensitivity of conative capabilities to environmental factors. Both CPBL and PjBL's systematic reflection activities through reflection reports, peer evaluations, and progress-sharing sessions effectively supported their evaluation and visualization capabilities, aligning with Stefanou et al.'s (2013) research, which indicates that these environments enable students to constantly monitor their understanding and develop self-regulation strategies. In contrast, traditional learning's instructor-centered seminar format with rotating expert lecturers provided minimal reflection and feedback opportunities, resulting in lower performance in these dimensions. The absence of systematic reflection and feedback activities in traditional learning demonstrates the importance of deliberate reflection structures in developing evaluation and visualization capabilities, suggesting that intentional pedagogical design is important rather than emerging naturally from content delivery alone.

These findings reveal that implementation characteristics serve as critical mediating factors between T&L strategies and students' learning effort, supporting Hadgraft and Kolmos's (2020) argument that specific implementation factors determine impact more than general instructional approaches. Han's (2021) research reinforces this by demonstrating that scaffolding had the strongest positive path to students' engagement among teaching strategies, emphasizing that implementation quality determines effectiveness. The differential

impacts across planning, acting, and reflecting constructs provide empirical evidence for Atman's theoretical proposition that different conative capabilities have distinct developmental requirements and varying sensitivity to environmental factors. This understanding aligns with Honicke et al.'s (2020) assertion that teaching programs should foster T&L strategies that encourage persistence and effort while considering how course delivery and feedback enhance academic self-efficacy, regardless of broad pedagogical category.

The theoretical implications validate that learning effort from the perspective of conation is influenced by instructional environments through structural implementation features. This supports Borda et al.'s (2020) recommendations for prioritizing implementation quality and adopting realistic expectations for educational change that focus on specific environmental supports. The research demonstrates that the progression through Atman's conative taxonomy stages requires carefully orchestrated implementation characteristics that support each developmental phase, with key mediating factors including team configuration size, instructor scaffolding and feedback frequency, assessment patterns that promote accountability, collaboration duration and structure, and authentic problem engagement opportunities. These implementation characteristics serve as critical mediating factors that determine whether T&L strategies effectively develop students' planning, acting, and reflecting capabilities. These outcomes provide educators with concrete guidance for designing learning environments that systematically develop comprehensive learning effort capabilities essential for engineering success, emphasizing attention to these specific structural implementation characteristics.

Several limitations must be acknowledged in interpreting these findings. The cross-sectional design limits causal inferences about the relationship between T&L implementations and learning effort development, as students were not randomly assigned to pedagogical conditions and measured at a single time point after course completion. Additionally, the varying credit hours and course durations across programs (3-credit CPBL, 2-credit PJBL, 1-credit TL) may have confounded comparisons by providing different amounts of exposure time and engagement opportunities. Future research should address these limitations through longitudinal studies that track learning effort development across multiple courses and academic levels, examining how capabilities developed in introductory courses influence subsequent academic performance and persistence.

Conclusion

This study demonstrates that diverse T&L strategy implementations create significantly different outcomes in first-year students' learning efforts. The findings reveal that implementation characteristics serve as critical mediating factors, with team configuration size, instructor scaffolding and feedback frequency, assessment patterns that promote accountability, collaboration duration and structure, and authentic problem engagement opportunities substantially influencing educational. For engineering educators, these results emphasize the importance of aligning these mediating factors with pedagogical objectives, as the evidence shows that authentic problem engagement enhances analytical capabilities universally. The study demonstrates that approaches lacking these key implementation factors may undermine students' strategic learning development and persistence capabilities regardless of the underlying pedagogical philosophy. These insights provide engineering programs with evidence-based guidance for designing ITE courses that effectively prepare first-year students for the sustained learning efforts essential for engineering success by prioritizing these critical implementation characteristics as mediating factors that determine educational effectiveness over adherence to particular pedagogical labels.

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