Original Research

Flipped Classroom Critical Success Factors Across Science, Technology, Engineering, and Mathematics (STEM) and Non-STEM Disciplines in Senior High School

Stephen Jay Co[1], Arcturus Mancera[2]
[1]Institute of Education, Far Eastern University, Manila, Philippines
[2]Department of Senior High School, FEU High School, Manila, Philippines

Article Info

Article history:

Received 01 06, 2026
Revised 02 02, 2026
Accepted 02 22, 2026

Keywords:

Flipped Classroom Implementation
Critical Success Factors
STEM pedagogy
Disciplinary Pedagogical Differences
Secondary Education
Philippines

ABSTRACT

This study examined critical success factors for flipped classroom implementation among 88 senior high school teachers from private schools in Metro Manila, Philippines, with relatively balanced representation across STEM (n=41) and non-STEM (n=47) disciplines. Analysis revealed an emergent Foundation-Quality-Support model wherein technology infrastructure and pedagogical quality factors achieved comparable critical status, indicating necessary technology-pedagogy integration. Ten factors achieved critical success status (≥60% essential), with technology access and reliability rated most critical (75.0%). MANOVA demonstrated marginally significant multivariate effects, with Student Factors showing substantial disciplinary differences. STEM teachers rated student accountability, self-regulation, conceptual-procedural balance, and assessment alignment significantly higher than non-STEM teachers. Thematic analysis confirmed discipline-specific implementation patterns: STEM teachers emphasized technology infrastructure and content complexity management, whereas non-STEM teachers emphasized pedagogical facilitation. Both groups identified student engagement, institutional support, content design quality, and equitable access as universally critical factors. Findings demonstrate that disciplinary differences manifest as variations in degree rather than categorical distinctions, challenging one-size-fits-all approaches and advancing flipped classroom theory toward epistemologically grounded, discipline-responsive implementation frameworks appropriate for well-resourced school contexts.

Corresponding Author:

Stephen Jay Co
Institute of Education, Far Eastern University
Nicanor Reyes Street, Manila, Philippines
Email: sjco@feu.edu.ph

1. INTRODUCTION

The flipped classroom model represents a pedagogical approach that shifts direct instruction outside of class time through pre-recorded materials, allowing educators to reallocate face-to-face sessions toward active learning, application, and individualized student support (Bergmann & Sams, 2012). Contemporary meta-analytic findings reveal beneficial impacts on learner performance spanning various subject areas and educational levels. Strelan et al.'s (2020) comprehensive synthesis of 198 studies comprising 33,678 students found a moderate positive effect on student performance (g=0.50) compared to traditional instruction, with benefits evident regardless of discipline and primarily attributable to opportunities for structured, active learning and problem-solving. Similarly, Bredow et al.'s (2021) meta-analysis of 317 studies involving over 150,000 students found positive gains across academic, intrapersonal, and satisfaction-related outcomes, with effect sizes ranging from g=0.20 to g=0.53 for seven of eight outcomes examined. However, substantial heterogeneity in effects indicates that implementation quality and contextual factors significantly moderate outcomes.

Van Alten et al.'s (2021) meta-analysis of science education revealed that benefits emerged primarily when flipped approaches combined technology-mediated content delivery with inquiry-based in-class activities, rather than simply replacing lectures with videos while maintaining traditional exercises. This finding underscores that flipped classrooms represent necessary but insufficient conditions for improved learning—pedagogical quality determines whether technology inversion yields meaningful benefits. Implementation challenges dampen enthusiasm for curriculum reforms. In a systematic examination of K-12 flipped learning research, Satparam and Apps (2022) documented ongoing issues, including inadequate student engagement and responsibility, heightened demands on instructors, learner opposition to new pedagogical methods, disparities in technological resources, and implementation obstacles. These challenges are particularly acute in K-12 settings where increased teacher workload, student resistance due to unfamiliarity, and technology access inequities create significant implementation barriers (Fisher et al., 2019; Satparam & Apps, 2022). In higher education contexts, Akçayır and Akçayır (2018) found that while the most frequently reported advantage was improvement in student learning performance, challenges predominantly related to out-of-class activities, particularly inadequate student preparation prior to class. Baig and Yadegaridehkordi (2023) reinforced these findings, noting that despite demonstrated benefits, teachers struggle with effective implementation due to insufficient understanding of flipped learning benefits, appropriate pedagogical activities, and strategies for overcoming implementation challenges. Similar challenges have been documented in diverse contexts, including business education (Senali et al., 2022), nursing education (Wen & Young, 2024), and medical education (Mengesha et al., 2024), suggesting implementation barriers transcend disciplinary and geographic boundaries

Despite the growing body of research on flipped classroom implementation, critical methodological and theoretical limitations persist. The majority of identified critical success factors derive from expert opinion, theoretical frameworks, or literature synthesis rather than systematic empirical investigation of practicing teachers' classroom experiences (Satparam & Apps, 2022). This expert-driven approach creates a problematic disconnect: factors that appear theoretically important may not align with what teachers—who navigate actual implementation constraints—consistently identify as truly critical for success. When researchers rely on what sounds important in theory rather than what teachers in the classroom experience as critical in practice, schools do not have a guide to determine the best way to invest resources. This is especially difficult for schools with limited budgets that need to choose carefully.

Beyond methodological concerns, substantive theoretical limitations remain. Disciplinary differences in implementation requirements remain largely unexplored despite compelling literature evidence that knowledge structures and learning processes vary substantially between STEM and non-STEM fields (Biglan, 1973; Neumann et al., 2002). Recent systematic reviews have studied flipped classrooms across many educational settings (Baig & Yadegaridehkordi, 2023; Hew et al., 2021). However, little to no research has directly compared whether teachers from different disciplines consider different factors essential for successful implementation. STEM fields build hierarchically—each concept depends on mastering previous ones. Humanities and social sciences emphasize interpretation, context, and multiple valid perspectives. These fundamental epistemological differences likely require different pedagogical strategies. Yet current flipped classroom guidelines ignore these distinctions, treating implementation as universally applicable across disciplines. Recent Philippine research has documented strand-specific variations in technology-enhanced learning experiences, with STEM students reporting more positive evaluations of online learning implementation than non-STEM students (Co, 2025).

Geography adds another layer to these problems. The Philippines barely appears in flipped classroom research. Studies come overwhelmingly from Western countries and East Asia (Satparam & Apps, 2022). Filipino teachers face distinct challenges when they implement flipped classrooms. Technology infrastructure varies widely across schools. Internet connections drop frequently. Resources are limited. Cultural expectations about teaching and learning differ from Western norms. All of these conditions likely change which factors become critical for making flipped classrooms work. Initial Philippine research on flipped classrooms reveals mixed results, with some studies documenting effectiveness in specific subjects (Gonzales, 2019; Sablan & Prudente, 2022) while highlighting implementation challenges related to student preparedness, resource constraints, and technological readiness.

This study addresses these methodological, theoretical, and contextual gaps by empirically investigating critical success factors for flipped classroom implementation among Filipino senior high school

teachers, with explicit attention to disciplinary differences between STEM and non-STEM contexts. Particularly, this investigation seeks to address the following questions:
1. Which factors do teachers perceive as critical success factors for effective flipped classroom implementation?
2. Are there significant differences between STEM and non-STEM teachers in their perceptions of these critical success factors?
3. Which success factors most strongly discriminate between STEM and non-STEM teachers' perceptions?
4. What contextual explanations and challenges do teachers identify that influence the success of flipped classroom implementation?

2. METHOD

This study utilized a convergent parallel design combining qualitative and quantitative approaches (Creswell & Plano Clark, 2023), characterized by concurrent data gathering, separate analytical procedures, and subsequent synthesis to provide a comprehensive understanding of critical success factors and disciplinary differences. This design enabled triangulation—using qualitative findings to explain and contextualize quantitative patterns while allowing statistical analysis to identify systematic differences that qualitative data illuminated.

Purposive sampling yielded 88 Filipino senior high school teachers with active flipped classroom implementation experience from private schools in Metro Manila. The sample comprised a relatively balanced representation between STEM (n=41, 46.6%) and non-STEM (n=47, 53.4%) disciplines. STEM teachers taught specialized science subjects (biology, chemistry, physics) and advanced mathematics (pre-calculus, calculus, statistics). Non-STEM teachers represented humanities and social sciences (literature, politics, sociology, religious studies) and business-related disciplines (accounting, finance, management, economics). Inclusion criteria required: (a) current employment teaching senior high school in private schools, (b) minimum one semester of flipped classroom implementation experience, (c) active use of flipped approaches during data collection, and (d) voluntary informed consent.

A researcher-developed Critical Success Factors questionnaire comprised 30 items organized into six domains informed by the TPACK framework (Mishra & Koehler, 2006) and critical success factors literature (Rockart, 1979): Technology Infrastructure and Tools, Content Design and Structure, Pedagogical Strategies and Facilitation, Student Factors and Readiness, Assessment and Feedback Mechanisms, and Instructor and Institutional Factors. Items used 7-point Likert scales (1=Not Important, 7=Essential) assessing perceived importance for successful implementation.

Content validity was established through expert review by three doctoral-level specialists in education, yielding a Content Validity Index (CVI) of 0.89 (Polit et al., 2007). Reliability was assessed through pilot testing with 15 senior high school teachers experienced in flipped classroom implementation. Cronbach's alpha coefficients for the six domain subscales ranged from α=.82 to α=.91. In the full sample (n=88), domain reliabilities were as follows: Technology and Content Delivery (α=.844), Pedagogical Approaches (α=.755), Content Design and Structure (α=.827), Assessment and Feedback (α=.841), Student Factors (α=.846), and Instructor and Institutional Factors (α=.780), all indicating acceptable to excellent internal consistency. The questionnaire also included open-ended questions soliciting elaboration on critical success factors and implementation challenges, as well as demographic items capturing teaching discipline, teaching experience, flipped classroom implementation duration, school characteristics, student socioeconomic profile, and self-assessed implementation success.

Data collection occurred over five months following school review board approval and administrator permissions. The survey was distributed through an online platform, allowing participants to complete it asynchronously at their convenience. Response rate reached 71% of invited teachers (n=88 of 124 invited).

Critical success factor identification employed descriptive statistics (means, standard deviations, rankings) and top-box analysis, calculating the percentage rating each factor as “7–Essential,” with the empirically-derived threshold of ≥60% defining criticality. Multivariate analysis of variance (MANOVA) examined whether STEM and non-STEM teachers differed in their overall perceptions across the six critical success factor domains. Comparative analyses using independent samples t-tests revealed survey items demonstrating the most substantial disparities across cohorts. Effect sizes (including Cohen's d and partial eta-squared) quantified practical significance alongside statistical significance.

Reflexive thematic analysis (Braun & Clarke, 2019) examined open-ended responses from 83 participants (STEM n=38, non-STEM n=45). Reflexive thematic analysis (Braun & Clarke, 2019) examined open-ended responses from 83 of the 88 participants who provided written responses to qualitative questions (STEM n=38, non-STEM n=45; response rate 94.3%). Integration employed three strategies (Creswell & Plano Clark, 2023): comparing quantitative rankings with qualitative frequencies, using qualitative explanations to interpret quantitative differences, and identifying convergence-divergence patterns.

3. RESULTS AND DISCUSSION

3.1. Results

The study sample in Table 1 comprised 88 Filipino senior high school teachers, relatively balanced between STEM (*n*=41, 46.6%) and non-STEM (*n*=47, 53.4%) disciplines. Teaching experience varied, with 37.5% having less than three years of experience (*n*=33), 51.1% having three to ten years (*n*=45), and 11.4% having more than ten years (*n*=10). Participants' experience with the flipped classroom was also distributed: 29.5% (*n*=26) had less than one year, 54.5% (*n*=48) had one to three years, and 15.9% (*n*=14) had more than three years. Overall, teachers reported generally successful flipped classroom implementation experiences (*M*=5.39, *SD*=1.06 on a 7-point scale), with 40.9% rating their implementations as highly successful (ratings 6-7, *n*=36).

Table 1. Respondents' Characteristics and Flipped Classroom Implementation

Characteristic	*n*	%
Teacher Group		
STEM	41	46.6
Non-STEM	47	53.4
Teaching Experience		
< 3 years	33	37.5
3-10 years	45	51.1
> 10 years	10	11.4
Flipped Classroom Experience		
< 1 year	26	29.5
1-3 years	48	54.5
> 3 years	14	15.9
Implementation Success (m = 5.39, SD = 1.06)		
Below midpoint (3-4)	17	19.3
Moderate success (5)	35	39.8
High success (6-7)	36	40.9

3.1.1 Descriptive Statistics and Critical Success Factor Identification

Mean ratings ranged from 5.92 to 6.65 on the 7-point importance scale, indicating all factors were perceived as important (see Table 2). Ten factors achieved critical success status (≥60% top-box rating). The highest-rated individual factors were: technology access and reliability for students (*M*=6.60, *SD*=0.78, 75.00% top-box), clear alignment with learning objectives (*M*=6.65, *SD*=0.64, 72.73% top-box), clarity of explanations and instruction in pre-class materials (*M*=6.60, *SD*=0.69, 70.45% top-box), relevance of examples and applications (*M*=6.60, *SD*=0.65, 69.32% top-box), and alignment between assessments and learning objectives (*M*=6.60, *SD*=0.65, 69.32% top-box).

Table 2. Descriptive Statistics and Rankings for Critical Success Factors

Rank	Factors	Domain	*M*	*SD*	Top-Box %
1	Technology access and reliability for students	Technology and Content Delivery	6.60	0.781	75.00
2	Clear alignment with learning objectives	Content Design and Structure	6.65	0.644	72.73
3	Clarity of explanations and instruction in pre-class materials	Content Design and Structure	6.60	0.687	70.45
4	Relevance of examples and applications	Content Design and Structure	6.60	0.653	69.32
4	Alignment between assessments and learning objectives	Assessment and Feedback	6.60	0.653	69.32
5	Institutional support and resources	Instructor and Institutional Factors	6.43	0.944	65.91
6	Alignment of assessments with higher-order thinking skills	Assessment and Feedback	6.56	0.658	64.77
6	Instructor content creation proficiency	Instructor and Institutional Factors	6.49	0.773	64.77
7	Appropriateness of selected technology tools for student population and subject matter	Technology and Content Delivery	6.40	1.000	63.64
7	Instructor facilitation skills for active learning	Instructor and Institutional Factors	6.49	0.758	63.64
8	Active learning strategy selection for in-class sessions	Pedagogical Approaches	6.44	0.741	59.09
9	Clear connection between pre-class and in-class components	Pedagogical Approaches	6.45	0.710	57.95
10	Appropriate physical learning spaces	Instructor and Institutional Factors	6.35	0.845	56.82
11	Content accessibility across different devices	Technology and Content Delivery	6.27	1.036	55.68
11	Development of authentic assessment approaches	Assessment and Feedback	6.36	0.790	55.68
12	Balance between conceptual and procedural knowledge	Content Design and Structure	6.28	0.946	50.00
12	Content adaptation to discipline-specific needs	Content Design and Structure	6.31	0.807	50.00
12	Strategies to enhance student motivation	Student Factors	6.26	0.877	50.00
13	Quality and timeliness of feedback	Assessment and Feedback	6.27	0.813	48.86
13	Student accountability for pre-class preparation	Student Factors	6.25	0.848	48.86
14	Quality of pre-class multimedia content	Technology and Content Delivery	6.13	1.102	47.73
15	Integration of formative assessment throughout learning cycle	Assessment and Feedback	6.27	0.813	46.59
15	Integration of summative assessment aligned with flipped classroom methodology	Assessment and Feedback	6.22	0.864	46.59
16	Development of collaborative skills	Student Factors	6.11	0.952	45.45

Table 2 (cont.)

Rank	Factors	Domain	*M*	*SD*	Top-Box %
17	Interactive features in digital content (e.g., embedded questions)	Technology and Content Delivery	6.00	1.114	44.32
17	Problem-based learning implementation	Pedagogical Approaches	6.15	1.000	44.32
18	Optimal content length and segmentation	Technology and Content Delivery	6.14	0.899	43.18
18	Readiness and support for student self-regulation and autonomy	Student Factors	6.17	0.847	43.18
19	Case-based learning approaches	Pedagogical Approaches	6.06	1.032	39.77
20	Assessment of students' baseline technology proficiency	Student Factors	5.92	1.074	36.36

Note: CSF (Critical Success Factor) designation based on ≥60% rating as "Essential."

Domain-level analysis in Table 3 revealed Content Design and Structure as highest-rated (*M*=6.49, *SD*=0.58, 62.50% average top-box), followed by Instructor and Institutional Factors (M=6.44, SD=0.65, 62.78% average top-box), Assessment and Feedback Mechanisms (*M*=6.38, *SD*=0.58, 55.30% average top-box), Pedagogical Approaches (*M*=6.28, *SD*=0.67, 50.28% average top-box), Technology and Content Delivery (*M*=6.26, *SD*=0.75, 54.92% average top-box), and Student Factors (*M*=6.14, *SD*=0.73, 44.77% average top-box). Critical success factor rates, defined as the proportion of items within each domain achieving critical status, varied substantially: Instructor and Institutional Factors achieved the highest CSF rate (75%, 3 of 4 items), followed by Content Design and Structure (60%, 3 of 5 items), Assessment and Feedback (33.3%, 2 of 6 items), Technology and Content Delivery (33.3%, 2 of 6 items), and Pedagogical Approaches and Student Factors (0%, 0 of 4 and 0 of 5 items respectively).

Table 3. Critical Success Factor Distribution Across Domains

Domains	Mean	*SD*	Items	#CSF in Domain	Top-Box % (avg)
Content Design and Structure	6.49	0.582	5	3	62.50
Instructor and Institutional Factors	6.44	0.647	4	3	62.78
Assessment and Feedback	6.38	0.575	6	2	55.30
Pedagogical Approaches	6.28	0.671	4	0	50.28
Technology and Content Delivery	6.26	0.746	6	2	54.92
Student Factors	6.14	0.727	5	0	44.77

3.1.2. STEM vs. Non-STEM Differences

MANOVA revealed a marginally significant multivariate effect, $F(6,81)=2.17$, $p=.054$, partial $\eta^2=.139$, suggesting moderate practical differences in perceptions between disciplinary groups (see Table 4). Student Factors showed the most substantial difference, $F(1,86)=8.522$, $p=.004$, partial $\eta^2=.090$, with STEM teachers rating student readiness factors as significantly more critical (*M*=6.38, *SD*=0.56) than non-STEM teachers (*M*=5.94, *SD*=0.80). Assessment and Feedback showed a marginally significant difference, $F(1,86)=3.903$, $p=.051$, partial $\eta^2=.043$, with STEM teachers rating assessment factors higher (*M*=6.51, *SD*=0.46) than non-STEM teachers (*M*=6.27, *SD*=0.64). Instructor and Institutional Factors showed a trend toward significance, $F(1,86)=3.017$, $p=.086$, partial $\eta^2=.034$, with STEM teachers rating these factors slightly higher (*M*=6.57, *SD*=0.54) than non-STEM teachers (*M*=6.33, *SD*=0.71). No significant differences emerged for Technology and Content Delivery ($p=.115$), Pedagogical Approaches ($p=.537$), or Content Design and Structure ($p=.192$).

Table 4. STEM and Non-STEM Differences in Critical Success Factor Domains

Multivariate Test	value	*F*	df^1	df^2	*p*	Partial η^2
Pillai's Trace	0.139	2.17	6	81	0.054	0.139
Wilks' Lambda	0.861	2.17	6	81	0.054	0.139

Univariate Tests

Domains	STEM (*n*=41) *M*	STEM (*n*=41) *SD*	Non-STEM (*n*=47) *M*	Non-STEM (*n*=47) *SD*	Sum of Squares	*df*	Mean Square	*F*	*p*	Partial η^2
Technology & Content Delivery	6.39	0.595	6.14	0.846	1.39	1	1.39	2.541	0.115	0.029
Pedagogical Approaches	6.32	0.608	6.23	0.725	0.174	1	0.174	0.384	0.537	0.004
Content Design & Structure	6.58	0.472	6.41	0.659	0.581	1	0.581	1.731	0.192	0.020
Assessment & Feedback	6.51	0.458	6.27	0.644	1.247	1	1.247	3.903	0.051	0.043
Student Factors	6.38	0.564	5.94	0.796	4.147	1	4.147	8.522	0.004	0.090
Instructor & Institutional	6.57	0.542	6.33	0.713	1.233	1	1.233	3.017	0.086	0.034

Independent samples *t*-tests revealed six factors with statistically significant differences between STEM and non-STEM teachers ($p < .05$) and at least small-to-medium practical significance ($|d| \geq 0.30$) (see

Table 5). STEM teachers consistently rated all nine factors as more critical than their non-STEM counterparts. The largest differences emerged in three domains: student factors, content design, and institutional factors.

For student-related factors, STEM teachers placed significantly greater emphasis on balance between conceptual and procedural knowledge (*d*=0.62), student accountability for pre-class preparation (*d*=0.60), development of collaborative skills (*d*=0.56), readiness and support for student self-regulation (*d*=0.44), and strategies to enhance student motivation (*d*=0.44). Regarding institutional factors, STEM teachers rated instructor content creation proficiency (*d*=0.55) and appropriate physical learning spaces (*d*=0.53) as significantly more critical. Additionally, STEM teachers emphasized alignment between assessments and learning objectives (*d*=0.53) and integration of formative assessment throughout the learning cycle (*d*=0.45) more strongly than non-STEM teachers. These disciplinary differences reflect STEM's hierarchical knowledge structures requiring structured accountability, prerequisite mastery, and systematic assessment alignment, contrasting with non-STEM's more flexible interpretive approaches.

Table 5. Independent Samples *T*-Test Results

Factors	STEM *M*	STEM *SD*	NON-STEM *M*	NON-STEM *SD*	*t*	*p*	*d*
A. Technology and Content Delivery							
A1. Quality of pre-class multimedia content	6.22	1.17	6.04	1.04	-0.750	0.456	-0.160
A2. Technology access and reliability for students	6.76	0.58	6.47	0.91	-1.746	0.084	-0.373
A3. Interactive features in digital content (e.g., embedded questions)	6.07	1.03	5.94	1.19	-0.573	0.568	-0.123
A4. Optimal content length and segmentation	6.29	0.75	6.00	1.00	-1.535	0.129	-0.328
A5. Content accessibility across different devices	6.41	0.87	6.15	1.16	-1.203	0.232	-0.257
A6. Appropriateness of selected technology tools for student population and subject matter	6.59	0.67	6.23	1.20	-1.660	0.101	-0.355
B. Pedagogical Approaches							
B1. Active learning strategy selection for in-class sessions	6.51	0.71	6.38	0.77	-0.815	0.417	-0.174
B2. Clear connection between pre-class and in-class components	6.46	0.67	6.45	0.75	-0.109	0.914	-0.023
B3. Problem-based learning implementation	6.22	0.99	6.09	1.02	-0.627	0.533	-0.134
B4. Case-based learning approaches	6.1	0.86	6.02	1.17	-0.344	0.732	-0.074
C. Content Design and Structure							
C1. Clear alignment with learning objectives	6.68	0.61	6.62	0.68	-0.477	0.635	-0.102
C2. Balance between conceptual and procedural knowledge	6.59	0.63	6.02	1.09	-2.907	0.005	-0.621
C3. Clarity of explanations and instruction in pre-class materials	6.63	0.62	6.57	0.74	-0.404	0.687	-0.086
C4. Relevance of examples and applications	6.68	0.57	6.53	0.72	-1.084	0.282	-0.232
C5. Content adaptation to discipline-specific needs	6.29	0.78	6.32	0.84	0.153	0.879	0.032
D. Assessment and Feedback							
D1. Integration of formative assessment throughout learning cycle	6.46	0.67	6.11	0.89	-2.096	0.039	-0.448
D2. Integration of summative assessment aligned with flipped classroom methodology	6.39	0.70	6.06	0.97	-1.791	0.077	-0.383
D3. Alignment between assessments and learning objectives	6.78	0.53	6.45	0.72	-2.460	0.016	-0.526
D4. Alignment of assessments with higher-order thinking skills	6.61	0.63	6.51	0.69	-0.702	0.484	-0.150
D5. Quality and timeliness of feedback	6.39	0.74	6.17	0.87	-1.272	0.207	-0.272
D6. Development of authentic assessment approaches	6.41	0.84	6.32	0.76	-0.563	0.575	-0.120
E. Student Factors							
E1. Student accountability for pre-class preparation	6.51	0.71	6.02	0.90	-2.816	0.006	-0.602
E2. Readiness and support for student self-regulation and autonomy	6.37	0.70	6.00	0.93	-2.058	0.043	-0.440
E3. Strategies to enhance student motivation	6.46	0.78	6.09	0.93	-2.055	0.043	-0.440
E4. Development of collaborative skills	6.39	0.83	5.87	0.99	-2.631	0.01	-0.562
E5. Assessment of students' baseline technology proficiency	6.15	0.82	5.72	1.23	-1.868	0.065	-0.399
F. Instructor and Institutional Factors							
F1. Instructor facilitation skills for active learning	6.54	0.75	6.45	0.78	-0.552	0.582	-0.118
F2. Instructor content creation proficiency	6.71	0.60	6.30	0.86	-2.556	0.012	-0.546
F3. Appropriate physical learning spaces	6.59	0.71	6.15	0.91	-2.489	0.015	-0.532
F4. Institutional support and resources	6.44	0.98	6.43	0.93	-0.067	0.947	-0.014

3.1.3. Thematic Analysis of Implementation Successes and Challenges

Reflexive thematic analysis (Braun & Clarke, 2019) of open-ended responses from 83 teachers (STEM *n*=38, Non-STEM *n*=45) following a six-phase iterative process of familiarization, systematic coding, theme generation, theme review, theme definition, and reporting identified six critical success factors: (1) effective pedagogical facilitation, (2) student preparedness and accountability, (3) quality learning materials, (4) technology infrastructure, (5) content complexity management, and (6) institutional support, as well as seven implementation challenges, revealing significant strand-based differences.

Effective pedagogical facilitation emerged as the predominant success factor, mentioned by 60.2% of teachers overall, though Non-STEM teachers emphasized this significantly more than STEM teachers (68.9% vs. 50.0%). A HUMSS teacher explained: "*pedagogical approaches, content design and structure, and assessment and feedback are essential...because they ensure that learning is student-centered and aligned with* *the strand's focus on critical thinking and communication*" (Teacher #6). Student preparedness and accountability (34.9%) and quality learning materials (28.9%) were universally valued across strands.

Conversely, STEM teachers emphasized technology infrastructure substantially more than Non-STEM teachers (26.3% vs. 11.1%), reflecting dependence on computational tools and platforms. One STEM teacher noted: "*Technology access and reliability for students, Alignment between assessments and learning objectives, Appropriateness of selected technology tools for student population and subject matter*" (Teacher #60).

Implementation challenges were led by time and resource constraints (26.5%), a universal concern. However, STEM teachers more frequently cited content complexity (21.1% vs. 8.9%), explaining: "*Mathematics subject are skill based and procedural. Something that is difficult to self learn...I tried to address this by giving out self-made lecture videos but still it rely heavily on student initiative*" (Teacher #65). Notably, student diversity and readiness gaps emerged exclusively among Non-STEM teachers (8.9% vs. 0%), with one HUMSS teacher describing: "*Varying perspectives and maturity levels. Topics in HUMSS—such as politics, ethics, or culture—can be sensitive or controversial. Without in-class framing, students might misinterpret or oversimplify content consumed at home*" (Teacher #48).

3.2. Discussion

This study's convergent findings illuminate why flipped classroom implementation success varies substantially across teachers and disciplines, revealing a Foundation-Quality-Support model emerging from the data wherein technology infrastructure constitutes necessary but insufficient conditions, pedagogical quality factors determine learning outcomes, and institutional support enables sustainability. This three-tiered framework synthesizes teachers' perceptions of critical success factors into a coherent implementation structure.

While technology infrastructure emerged as foundational—consistent with Philippine connectivity challenges—pedagogical quality factors achieved comparable critical status. This pattern challenges technology-centric assumptions about flipped learning. Teachers appear to recognize that reliable access enables implementation but does not guarantee learning improvements. Rather, pedagogical design quality—clear objectives, engaging materials, appropriate complexity—determines whether technology inversion yields meaningful benefits or merely digitizes traditional lectures. This Foundation-Quality-Support framework aligns with Oudbier et al.'s (2022) identification of task characteristics and activity design as critical alongside technological factors.

The observed disciplinary differences in flipped classroom requirements operate as variations in degree rather than categorical distinctions—STEM and non-STEM teachers share substantial common ground regarding most critical success factors while exhibiting meaningful differences in specific areas. This pattern mirrors findings from comparative studies showing that while disciplinary epistemologies shape pedagogical emphases, successful technology-enhanced learning requires attention to both universal design principles and discipline-specific adaptations (Senali et al., 2022; Yang & Balinas, 2025).

STEM teachers' heightened emphasis on student accountability, self-regulation, and balance between conceptual and procedural knowledge reflects hierarchical knowledge structure requirements. In cumulative disciplines where later concepts build on earlier foundations, inadequate prerequisite mastery and incomplete preparation create cascading comprehension failures. One STEM teacher's observation that "Mathematical content builds so cumulatively that if students don't master earlier concepts, they're lost in later material" captures this epistemological constraint. The flipped classroom potentially addresses hierarchical knowledge challenges by providing multiple encounters with foundational concepts through pre-class videos before tackling applications, but only if students actually engage with preparatory materials—hence STEM teachers' heightened accountability emphasis. STEM teachers also emphasized instructor content creation proficiency and appropriate physical learning spaces, reflecting disciplinary dependencies that extend beyond general connectivity to include specialized computational environments and structured spaces for problem-solving activities.

Conversely, the qualitative findings revealed Non-STEM teachers' greater emphasis on pedagogical facilitation, with nearly seven in ten Non-STEM teachers versus half of STEM teachers identifying effective facilitation as critical. This reflects horizontal knowledge structures emphasizing interpretation, argumentation, and contextual application. This pattern aligns with research on social studies and humanities instruction emphasizing discussion orchestration and multiple valid interpretations (Burce & Callo, 2024; Bursa & Köse, 2020; Erbil & Kocabaş, 2020; İşçi & Yazıcı, 2023). The interpretive nature of these disciplines creates distinct implementation priorities focused on facilitating dialogue and managing diverse perspectives rather than ensuring sequential mastery.

Despite disciplinary differences, substantial shared perceptions emerged regarding multiple critical success factors, suggesting universal requirements transcending epistemological variations. Student engagement and motivation appeared uniformly critical across both groups, indicating that flipped classroom success fundamentally depends on motivating students to complete preparatory work regardless of discipline. Both STEM and non-STEM teachers recognized pedagogical design principles—clear learning objectives, engaging presentation, appropriate complexity, structured activities—as broadly applicable despite disciplinary content differences. Institutional support emerged uniformly in qualitative responses, suggesting that teachers across disciplines recognize organizational enablers as critical for sustainable implementation.

Integration of quantitative and qualitative findings revealed substantial agreement, strengthening confidence in results. Factors achieving critical status in quantitative ratings consistently appeared as prominent themes in qualitative responses, validating both measurement approaches. However, institutional support received moderate quantitative importance ratings yet emerged prominently in qualitative sustainability discussions, suggesting that teachers recognize institutional support as more critical through implementation experience than through abstract importance judgments.

For school administrators, findings suggest that flipped classroom initiatives require three-tiered investment: technology infrastructure as foundation (prioritizing reliable connectivity and discipline-appropriate tools), pedagogical quality development as effectiveness driver (emphasizing instructional design competencies and content structuring expertise), and institutional support as sustainability enabler (providing ongoing professional development, resource allocation, and administrative backing). For teacher professional development, preparation programs should balance universal instructional design competencies with discipline-responsive calibration: STEM teachers particularly need support developing accountability mechanisms, prerequisite identification systems, and scaffolded materials addressing procedural-conceptual duality, while non-STEM teachers particularly need facilitation skill development, diverse assessment design, and contextualization strategies. For Philippine policy makers, infrastructure inequities require systemic solutions—students lacking home internet access cannot productively engage regardless of pedagogical quality.

Limitations warrant consideration. Purposive sampling from private Metro Manila schools limits generalizability to public schools or rural contexts facing more severe resource constraints. Self-reported implementation success rather than objective student outcome measures prevents validation of whether factors teachers identify as critical actually predict improved learning. Cross-sectional design prevents examining how critical success factor perceptions evolve with increasing implementation experience. Broad STEM versus non-STEM categories may mask within-category variation.

4. CONCLUSION

This mixed-methods investigation of senior high school teachers advances understanding in three ways. First, it provides empirically-validated identification of critical success factors through systematic teacher consensus, revealing a Foundation-Quality-Support model wherein technology infrastructure constitutes necessary conditions, pedagogical quality determines effectiveness, and institutional support enables sustainability. Second, it demonstrates that disciplinary differences in flipped classroom requirements manifest as variations in degree rather than categorical distinctions, with STEM teachers emphasizing student accountability, prerequisite clarity, and computational tools more strongly, while non-STEM teachers emphasize facilitation skills, assessment variety, and real-world contextualization more strongly, yet substantial shared perceptions indicate universal requirements transcending epistemological differences. Third, convergent integration of quantitative importance ratings and qualitative implementation narratives reveals both what teachers identify as critical and why these factors prove essential in practice—STEM's hierarchical knowledge structures increase accountability criticality because incomplete prerequisite mastery undermines cumulative concept development, while non-STEM's horizontal knowledge structures increase facilitation criticality because interpretive learning requires skilled discussion orchestration. These findings hold particular significance for developing countries like the Philippines, where strategic resource allocation toward technology infrastructure, pedagogical quality, and institutional support becomes critical for successful implementation in resource-constrained educational environments.

Limitations warrant consideration when interpreting these findings. Purposive sampling from private Metro Manila schools limits generalizability to public schools or rural contexts facing more severe resource constraints. The study relied on self-reported implementation success rather than objective student outcome measures, and the cross-sectional design prevents examining how perceptions evolve with sustained implementation experience.

Future research should examine whether the identified critical success factors apply equally across diverse school contexts or whether resource-constrained settings reveal different implementation priorities. Comparative studies between well-resourced and under-resourced schools could identify minimum viable requirements for successful flipped classroom adoption and cost-effective strategies for establishing foundational conditions in budget-limited environments, particularly addressing technology infrastructure gaps and institutional support needs in Philippine public schools and other developing country contexts. The research challenges simplistic technology-centric or one-size-fits-all implementation approaches, instead revealing that flipped classroom success requires coordinated attention to technological foundations, pedagogical quality, and institutional support, calibrated appropriately for disciplinary epistemologies and local contexts.

DECLARATION OF INTEREST

The authors declares no conflicts of interest.

RESEARCH FUNDING

This research received no external funding.

ETHICAL STATEMENT

This study was approved by the school research office following ethical guidelines for educational research.

AI USE STATEMENT

The authors used ChatGPT for language improvement and formatting assistance.

REFERENCES

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education, 126*, 334-345. https://doi.org/10.1016/j.compedu.2018.07.021

Baig, M. I., & Yadegaridehkordi, E. (2023). Flipped classroom in higher education: A systematic literature review and research challenges. *International Journal of Educational Technology in Higher Education, 20*, Article 61. https://doi.org/10.1186/s41239-023-00430-5

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day.* International Society for Technology in Education.

Bhattacharyya, M. (2025). Effectiveness of flipped classroom in higher education: Opportunities and challenges. *International Journal of Research and Innovation in Applied Science, 10*(10), 1271–1277. https://doi.org/10.51584/IJRIAS.2025.10100000110

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology, 57*(3), 195-203. https://doi.org/10.1037/h0034701

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589-597. https://doi.org/10.1080/2159676X.2019.1628806

Bredow, C. A., Roehling, P. V., Knorp, A. J., & Sweet, A. M. (2021). To flip or not to flip? A meta-analysis of the efficacy of flipped learning in higher education. *Review of Educational Research, 91*(6), 878-918. https://doi.org/10.3102/00346543211019122

Burce, A. D., & Callo, E. C. (2024). Flipped classroom strategy in promoting critical thinking in social science. *World Journal of Advanced Research and Reviews, 22*(2), 2111–2137. https://doi.org/10.30574/wjarr.2024.22.2.1638

Bursa, S., & Köse, T. Ç. (2020). The effect of flipped classroom practices on students' academic achievement and responsibility levels in social studies course. *The Turkish Online Journal of Distance Education, 21*(3), 143–159. https://doi.org/10.17718/tojde.803390

Co, S. J. (2025). Student evaluation of blended learning implementation and faculty performance with online components: A comparative analysis across senior high school grade levels and academic strands. *International Journal on Open and Distance e-Learning, 10*(2). https://doi.org/10.58887/ijodel.v10i2.287

Creswell, J. W., & Plano Clark, V. L. (2023). *Designing and conducting mixed methods research* (4th ed.). SAGE Publications.

Erbil, D. G., & Kocabaş, A. (2020). Flipping the 4th grade social studies course in a cooperative way: Effects on academic achievement and motivation. *Studies in Educational Evaluation, 66*, Article 100878. https://doi.org/10.1016/j.stueduc.2020.100878

Fisher, R., LaFerriere, R., & Rixon, A. (2019). Flipped learning: An effective pedagogy with an Achilles' heel. *Innovations in Education and Teaching International, 57*(5), 609-620. https://doi.org/10.1080/14703297.2019.1635904

Gonzales, R. R. (2019). Flipped classroom approach: Experiences from a Philippine state university. *The Normal Lights, 13*(2), 67–89. https://doi.org/10.56278/tnl.v13i2.1386

Hew, K. F., Bai, S., Dawson, P., & Lo, C. K. (2021). Flipped classroom: What we know and what we don't. *Educational Research Review, 33*, Article 100393. https://doi.org/10.1016/j.edurev.2021.100393

İşçi, T. G., & Yazıcı, K. (2023). The effect of the use of the flipped learning model in the social studies course on the students' academic success and higher-order thinking skills. *International E-Journal of Educational Studies, 7*(13), 46-64. https://doi.org/10.31458/iejes.1216865

Mengesha, A. K., Simegn, G. L., Chanie, M. G., & Agegn, S. B. (2024). Assessing the effectiveness of flipped classroom teaching in medical education: A quasi-experimental study. *BMC Medical Education, 24*, Article 6105. https://doi.org/10.1186/s12909-024-06105-7

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Neumann, R., Parry, S., & Becher, T. (2002). Teaching and learning in their disciplinary contexts: A conceptual analysis. *Studies in Higher Education, 27*(4), 405-417. https://doi.org/10.1080/0307507022000011525

Oudbier, J., Spaai, G., Timmermans, K., Boerboom, T., Jaarsma, D., Dolmans, D., & Muijtjens, A. (2022). Enhancing the effectiveness of flipped classroom in health science education: A state-of-the-art review. *BMC Medical Education, 22*, Article 34. https://doi.org/10.1186/s12909-021-03052-5

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health, 30*(4), 459-467. https://doi.org/10.1002/nur.20199

Rockart, J. F. (1979). Chief executives define their own data needs. *Harvard Business Review, 57*(2), 81-93.

Sablan, J. R., & Prudente, M. (2022). Traditional and flipped learning: Which enhances students' academic performance better? *International Journal of Information and Education Technology, 12*(1), 54–59. https://doi.org/10.18178/ijiet.2022.12.1.1586

Satparam, J. R., & Apps, T. (2022). A systematic review of the flipped classroom research in K-12: Implementation, challenges and effectiveness. *Journal of Education, Management and Development Studies, 2*(1), 35-51. https://doi.org/10.52631/jemds.v2i1.71

Senali, M. G., Iranmanesh, M., Ghobakhloo, M., Gengatharen, D., Tseng, M.-L., & Nilsashi, M. (2022). Flipped classroom in business and entrepreneurship education: A systematic review and future research agenda. *The International Journal of Management Education, 20*(1), Article 100614. https://doi.org/10.1016/j.ijme.2022.100614

Strelan, P., Osborn, A., & Palmer, E. (2020). The flipped classroom: A meta-analysis of effects on student performance across disciplines and education levels. *Educational Research Review, 30*, Article 100314. https://doi.org/10.1016/j.edurev.2020.100314

Van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2021). Self-regulated learning support in flipped learning videos enhances learning outcomes. *Computers & Education, 158*, Article 104000. https://doi.org/10.1016/j.compedu.2020.104000

Wen, Z., & Young, L. (2024). Factors and strategies in the implementation of flipped classrooms among nursing students. *Journal of Higher Education Research, 12*(1), 121–146. https://doi.org/10.70228/YJHER2024003

Yang, J., & Balinas, J. (2025). Flipped classroom in China: A review of research, implementation, and challenges. *Comparative Education Research, 3*(1), 1-25. https://doi.org/10.54097/sfxbz957