Digitally-Enhanced Physical Education: Effects of Flipped Classroom on Motivation, Self-Directed Learning, and Aerobic Skills Among University Students in China

Su Fan, Wei Huisuan, Muhd Khaizer Bin Omar, and Yue Shuang

Abstract – **The rapid digitalisation of higher education has created both opportunities and pressures for pedagogical reform, particularly in disciplines where conventional instruction struggles to engage students and cultivate independent learning habits. This study examined whether the flipped classroom—a digitally mediated pedagogical model—can address these challenges in university aerobics education in China. Using a quasi-experimental pretest–posttest control group design, 384 undergraduate students at China Three Gorges University (Hubei Province) were randomly assigned to either a 16-week flipped classroom intervention (n = 192) or conventional lecture-based instruction (n = 192). Three outcomes were assessed: learning motivation, self-directed learning ability, and aerobic skill performance. The experimental group significantly outperformed the control group across all three outcomes at posttest: learning motivation (t = 4.42, p < .001, d = 0.45), self-directed learning ability (t = 7.48, p < .001, d = 0.77), and aerobic skill performance (t = 12.48, p < .001, d = 0.41). Logistic regression analyses revealed that flipped classroom participants were 9.61 times more likely to achieve high motivation and 4.74 times more likely to achieve excellent aerobic skill performance relative to peers in traditional instruction. These findings provide the first large-sample controlled evidence that digital flipped classroom instruction effectively enhances motivation, metacognitive capacity, and practical skill outcomes in Chinese university physical education, with direct implications for AI-era educational reform.**

Keywords – **flipped classroom; aerobics; physical education; digital pedagogy; self-directed learning; quasi-experimental**

I. INTRODUCTION

The conference theme of ICREE 2026—Education in the Age of Artificial Intelligence and Digitalization—captures a profound transformation currently reshaping higher education globally. Digital technologies are no longer supplementary tools; they are increasingly the primary architecture through which instruction is designed and experienced.

Within this transformation, the flipped classroom has emerged as one of the most pedagogically coherent responses to the challenge of digitally-mediated learning: rather than treating online content as a substitute for human instruction, it uses pre-class digital resources to liberate face-to-face time for the interactive, feedback-rich practice that deep and durable learning requires (Cheng et al., 2018; Strelan et al., 2020).

In Chinese university physical education, this digital transformation is both urgent and unevenly realised. National surveys show that only 38% of students report genuine interest in aerobics classes—one of the most widely enrolled compulsory PE courses—with the majority citing monotony and the absence of personalised feedback as primary demotivators (Bores-Garcia et al., 2024). Despite national informatisation mandates such as the 2018 Education Informatization 2.0 Action Plan, fewer than 2% of flipped classroom studies in China have examined sports-related disciplines, and none has systematically tested the model in aerobics with rigorous experimental controls (He & Li, 2022; Qian et al., 2023). This represents a critical gap: aerobics requires simultaneous processing of rhythmic, coordinative, and aesthetic information—precisely the multi-dimensional demands that the flipped model's structured three-phase architecture is theoretically equipped to address.

This study directly addresses that gap. Drawing on Constructivist Learning Theory, Self-Regulated Learning Theory, and Cognitive Load Theory as an integrated framework, it examines whether flipped classroom instruction produces significant and theoretically patterned improvements in learning motivation, self-directed learning ability, and aerobic skill performance among Chinese university aerobics students—and asks what the pattern of effects reveals about the mechanisms through which digital pedagogy produces learning in movement-based educational contexts.

II. PROBLEM STATEMENT

Despite the increasing emphasis on digital transformation in higher education, the pedagogical problems embedded in university physical education have not been sufficiently resolved. Aerobics instruction, in particular, remains heavily dependent on teacher demonstration, collective imitation, and repetitive practice. Such conventional formats often leave limited time for individual feedback, differentiated correction, and sustained self-practice. This problem is especially salient because aerobics requires learners to coordinate rhythm, movement accuracy, body control, and expressive performance simultaneously. Under live demonstration-based instruction, students are required to observe, remember, and execute complex movement sequences within the same limited class period, which may increase cognitive load and weaken both motivation and skill acquisition (Sweller et al., 2011). Existing evidence also suggests that many students show limited interest in aerobics classes and lack effective

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strategies for independent pre-class practice (Bores-Garcia et al., 2024; Bazrafkan et al., 2023).

Although the flipped classroom has been widely discussed as an effective digital pedagogy, its application in physical education remains uneven and insufficiently examined. Previous meta-analyses have reported positive effects of flipped learning on academic achievement and motivation across disciplines (Cheng et al., 2018; Strelan et al., 2020), and recent studies have begun to confirm its potential for motor skill learning in physical education (Liu et al., 2025; Wu et al., 2025). However, much of the existing research focuses on general learning outcomes, student satisfaction, or broad physical education contexts, while empirical evidence from university aerobics remains limited. More importantly, few studies have examined whether flipped classroom instruction can simultaneously improve students' learning motivation, self-directed learning ability, and aerobic skill performance within a controlled experimental design.

This gap is important because digital pedagogy should not be evaluated merely by whether digital tools are introduced into teaching, but by whether these tools restructure the learning process in ways that solve persistent pedagogical problems. In aerobics education, the flipped classroom may offer a theoretically grounded solution by moving movement observation and basic knowledge acquisition before class, freeing class time for peer coaching and corrective feedback, and extending learning through post-class reflection. Therefore, this study investigates whether a structured flipped classroom intervention can address the motivational, self-regulatory, and skill-acquisition limitations of conventional aerobics instruction among Chinese university students. Specifically, this study focuses on the following research questions:

1. Does flipped classroom instruction significantly improve university students' learning motivation, self-directed learning ability, and aerobic skill performance compared with conventional instruction?
2. Which outcome shows the strongest improvement under flipped classroom instruction, and is the pattern of effects consistent with Constructivist Learning Theory, Self-Regulated Learning Theory, and Cognitive Load Theory?
3. Does flipped classroom instruction produce meaningful distributional changes in students' learning outcomes, such as increasing the likelihood of high motivation and excellent aerobic skill performance?

III. LITERATURE REVIEW

Flipped Classroom: Evidence and Mechanisms

The flipped classroom inverts the conventional instructional sequence: students acquire foundational knowledge through pre-class digital resources, then devote face-to-face time to collaborative application and targeted skill refinement (Baig & Yadegaridehkordi, 2023). Meta-analytic evidence affirms its effectiveness across disciplines: Cheng et al. (2018) reported effect sizes of d = 0.33–0.62 on academic achievement; Strelan et al. (2020), synthesising 173 studies, found consistent positive effects on both cognitive outcomes and student motivation. In physical education, Liu et al.'s (2025) meta-analysis of 47 studies reported a significant effect on motor skill performance (d = 0.58), and Wu et al. (2025) documented significant motivational benefits (d = 0.58 for intrinsic motivation). The model's theoretical strength rests on two pillars: constructivist peer scaffolding within Vygotsky's (1978) Zone of Proximal Development during in-class collaborative practice, and the cultivation of self-regulatory capacity through Zimmerman's (2002) forethought–performance–reflection cycle made obligatory by the weekly structure.

Self-Directed Learning in the Digital Age

Self-directed learning has become a defining competency of AI-era education, as automated systems increasingly handle routine tasks while demanding learners capable of independently identifying, pursuing, and evaluating knowledge (Bayram et al., 2023; Kim & Lim, 2021). Zimmerman's (2002) cyclical self-regulated learning model provides the key theoretical insight: self-direction develops through repeated, structured practice in goal-setting, self-monitoring, and self-evaluation—not through passive exposure. The flipped classroom is the only common instructional format that makes all three phases structurally obligatory on a weekly basis, making it a powerful vehicle for cultivating the self-regulatory habits that digital-age learners require.

Aerobics Instruction: A Persistent Pedagogical Challenge

Aerobics presents distinctive instructional challenges under conventional formats. Students must simultaneously observe movement sequences and begin forming motor representations during live demonstration—a dual-task demand that generates high extraneous cognitive load precisely when germane processing for motor schema formation is most needed (Sweller et al., 2011). Data from Hubei Province indicate that 72% of aerobics students lack effective strategies for independent pre-class practice, and students master only 53% of core techniques after a standard 16-week conventional course (Bazrafkan et al., 2023; Kaplan et al., 2022). The flipped model resolves these structural deficits by decoupling observation from execution through pre-class video, creating in-class time for corrective practice, and imposing the self-regulatory cycle that independent aerobics skill development requires.

IV. METHOD

Research Design and Participants

A quasi-experimental pretest–posttest control group design with stratified random assignment was employed (see Figure 1). A total of 384 undergraduate students (268 female, 69.8%; 116 males, 30.2%; Mage = 19.3 years, SD = 0.8) enrolled in compulsory aerobics courses at China Three Gorges University, Hubei Province participated during the 2024–2025 academic year. All were non-sports-major students with no formal prior aerobics training. Four intact classes (n = 192) were randomly allocated to the flipped classroom condition; four classes (n = 192) formed the control condition. Both groups were taught by the same instructor using the same curriculum, facilities, and schedule

(two 90-minute sessions per week; 32 instructional hours over 16 weeks). Ethical approval was obtained from China Three Gorges University Ethics Committee (No. SD20251005). Pre-test equivalence was confirmed across all outcome variables prior to the intervention (all $p > .05$).

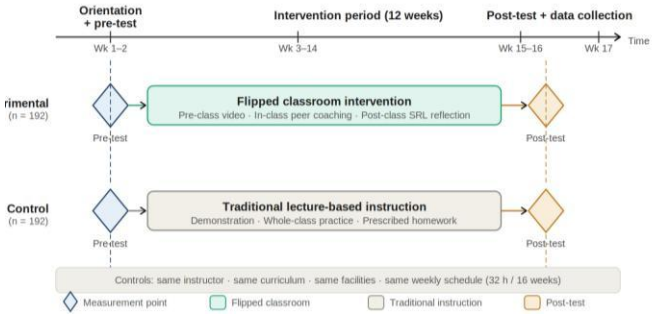


Figure 1. Quasi-experimental pretest–posttest control group research design with timeline.

Note. The sole difference between conditions was instructional format. All other variables—instructor, curriculum content, facilities, and schedule—were held constant across both groups.

Intervention

The 16-week flipped classroom intervention operated through a structured three-phase weekly cycle grounded in the integrated theoretical framework (Figure 2). In the pre-class phase (3–4 days before each session), students viewed 8–12-minute instructional videos incorporating guided-observation tasks and were required to complete a self-assessment quiz (minimum passing threshold: 70%) before class. The instructor reviewed completion analytics before each session to identify common difficulties. In the in-class phase (90 minutes), a 15-minute introduction addressed pre-class analytics findings; the main phase (65 minutes) was devoted to small-group peer coaching using a standardised observation protocol, with the instructor providing targeted corrective feedback rather than whole-class re-demonstration; a 10-minute consolidation assigned post-class tasks. In the post-class phase (2–3 days after class), students recorded practice videos, completed structured reflection journals using three standardised prompts (what improved; what requires attention; what strategy to apply next), and participated in peer video critique forums. The control group received conventional lecture-and-demonstration instruction across the identical schedule, with prescribed homework between sessions.

Measures

Learning motivation and self-directed learning ability were assessed using the Aerobics Course Engagement Scale (Chen, 2023), a validated 10-item instrument comprising two 5-item subscales rated on a 5-point Likert format (1 = strongly disagree; 5 = strongly agree; range 5–25 per subscale; Cronbach's α = .83–.93 in the present sample). Aerobic skill performance was assessed using the Aerobics Physical Fitness Testing Scale (Xian, 2022), an eight-item performance battery covering flexibility, strength, coordination, balance, and impromptu movement (total score 0–40; inter-rater ICC > .85). Assessments were administered at pretest (Week 1) and posttest (Week 17).

Data Analysis

All analyses were conducted in SPSS Version 27.0 (α = .05). Shapiro-Wilk tests confirmed non-normal distributions for all outcomes, so between-group posttest comparisons employed both independent-samples t-tests (robust at n = 190 per group by the central limit theorem) and Mann-Whitney U tests. Within-group changes were examined using paired-samples t-tests. Cohen's d effect sizes were computed using pooled standard deviations. Multivariable logistic regression models were constructed for each outcome, treating ordinal performance categories as dependent variables and group membership as the primary predictor, with academic major, residential origin, and household economic status entered as demographic covariates to control for baseline imbalances.

V. FINDINGS

Baseline Equivalence

Pre-test Mann-Whitney U tests confirmed no significant baseline differences between groups on motivation (U = 17,273, p = .467), self-directed learning (U = 17,733, p = .766), or aerobic skill (U = 17,834, p = .840). The three-pre-test equivalence null hypotheses (H01–H03) were retained, confirming that experimental and control groups were comparable on all primary outcomes prior to the intervention.

Primary Outcome Comparisons

Table 1 presents descriptive statistics and between-group posttest effect sizes. Both groups improved significantly on all three outcomes across 16 weeks (all within-group paired-t ps < .001), confirming that structured aerobics instruction of any format produces gains. At posttest, however, the experimental group significantly outperformed the control group on all three outcomes. The observed ordering of between-group effect sizes—d(self-directed learning) = 0.77 > d(motivation) = 0.45 > d(aerobic skill) = 0.41—matched the theoretically predicted ranking exactly, constituting convergent support for the integrated framework.

TABLE I: PRE-TEST AND POST-TEST DESCRIPTIVE STATISTICS WITH BETWEEN-GROUP EFFECT SIZES (N = 380)

Outcome variable	Group	Pre *M*	Pre *SD*	Post *M*	Post *SD*	Between-*d*
Learning motivation	Experimental	14.54	4.88	21.38	3.64	0.45***
	Control	14.18	5.01	19.10	3.41	
Self-directed learning	Experimental	14.07	4.81	22.89	2.86	0.77***
	Control	13.82	5.14	20.62	4.11	
Aerobic skill performance	Experimental	24.02	7.59	35.50	3.68	0.41***
	Control	24.05	7.32	32.26	6.77	

*Note. M = mean; SD = standard deviation. Between-d = Cohen's d for between-group posttest comparison. *** p < .001 for all between-group posttest differences confirmed by both t-test and Mann-Whitney U test. Learning motivation and self-directed learning scored on a 5–25 scale;*

aerobic skill performance on a 0–40 scale. Note the substantial reduction in post-test SD for aerobic skill in the experimental group (3.68 vs. pre-test 7.59), consistent with Cognitive Load Theory predictions regarding variance convergence following dual-task decoupling.

Logistic Regression: Distributional Effects

Table 2 presents key logistic regression findings adjusted for demographic covariates. These analyses reveal that the flipped classroom's effects were not merely reflected in mean score differences, but in fundamental distributional shifts across the performance spectrum. Within the experimental group, students were 9.61 times more likely to achieve 'good' motivation at posttest relative to their own pretest baseline—a near-tenfold increase in the probability of high motivational engagement. For aerobic skill, the within-group odds of achieving 'excellent' performance increased by a factor of 19.71. Between-group analyses confirmed that experimental students were 4.74 times more likely than control peers to achieve 'excellent' aerobic skill, and only 20% as likely to remain in the 'poor' self-directed learning category (OR = 0.20, p < .001). This near-elimination of persistent poor self-regulatory performance represents the study's most practically significant equity-oriented finding.

TABLE II: LOGISTIC REGRESSION: KEY ODDS RATIOS FOR OUTCOME CATEGORY TRANSITIONS (ADJUSTED FOR DEMOGRAPHIC COVARIATES)

Outcome	Category	*β*	*SE*	*OR*	*95% CI*	Comparison context
Learning motivation	Good	2.26	0.29	9.61	[5.44, 16.99]	Within Exp. (pre→post)
	Poor	−1.31	0.37	0.27	[0.13, 0.56]	Within Exp. (pre→post)
	Good	0.64	0.26	1.90	[1.14, 3.17]	Between groups (post)
Self-directed learning	Poor	−1.91	0.30	0.15	[0.08, 0.26]	Within Exp. (pre→post)
	Poor	−1.60	0.31	0.20	[0.11, 0.37]	Between groups (post)
Aerobic skill	Excellent	2.98	0.33	19.71	[10.25, 37.90]	Within Exp. (pre→post)
	Excellent	1.56	0.27	4.74	[2.96, 8.66]	Between groups (post)

Note. OR = Odds Ratio; CI = Confidence Interval. All models adjusted for academic major, residential origin, and household economic status as demographic covariates. 'Within Exp.' = comparison of posttest vs. pretest within the experimental group (reference: pretest baseline). 'Between groups' = experimental vs. control group at posttest (reference: control group). All OR entries shown are statistically significant at p < .05.

VI. DISCUSSION

The answer to the study's guiding question is affirmative: the flipped classroom works in Chinese university aerobics, and it does so through theoretically predictable mechanisms. Figure 2 presents the integrated framework linking the model's three structural phases to the three theoretical pillars and the observed outcome effects.

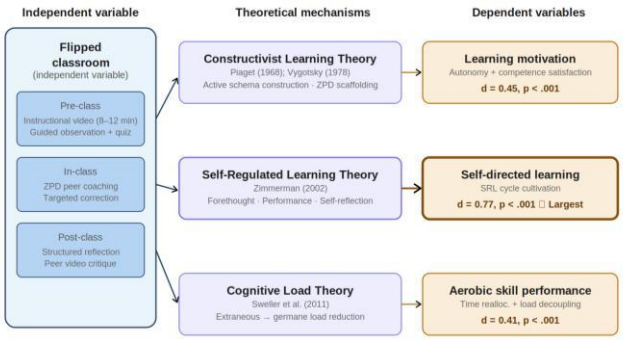


Figure 2. Integrated theoretical framework with empirically observed between-group effect sizes.

Note. The thicker border around the self-directed learning outcome reflects the largest observed effect (d = 0.77), consistent with the prediction that the flipped model's obligatory weekly self-regulatory demands most directly cultivate metacognitive capacity. The effect size ordering—SDL > Motivation > Aerobic Skill—matched the theoretically specified ranking.

The largest effect was observed for self-directed learning (d = 0.77), and this is precisely what the SRL-grounded theoretical framework predicts. The flipped model's most non-negotiable structural demand is behavioural self-regulation: students must complete pre-class preparation autonomously each week without instructor prompting. This demand does not merely encourage metacognitive engagement—it makes it structurally necessary for productive participation in in-class peer coaching activities. Repeated across 16 weekly cycles, this structure provides the sustained, scaffolded practice in forethought, performance monitoring, and self-reflection that Zimmerman (2002) identifies as the developmental engine of self-regulatory capacity. The dramatic variance convergence in the experimental group's post-test self-directed learning scores (SD from 5.11 to 2.86) indicates that this regulatory homogenisation occurred across the full cohort, including among students who entered the course with the weakest metacognitive foundations.

Motivation showed an intermediate effect (d = 0.45), explicable through Self-Determination Theory (Deci & Ryan, 1985): pre-class video engagement satisfied the autonomy need by allowing students to engage with movement demonstrations at their own pace before public performance was required; in-class peer coaching satisfied the relatedness need through collaborative practice; and incremental skill competence satisfaction the competence need. The logistic regression finding that experimental students were 9.61 times more likely to achieve 'good' motivation—a near-tenfold distributional shift—indicates that the model fundamentally restructured the motivational profile of the cohort, not merely nudged average scores upward.

Aerobic skill performance showed the smallest between-group effect (d = 0.41), which is theoretically interpretable rather than disappointing. Both groups engaged in identical volumes of physical practice; the flipped classroom's advantage lay in the quality and preparation-depth of that practice. Cognitive Load Theory (Sweller et al., 2011) explains the specific mechanism: pre-class videos decoupled the observation and execution phases that live demonstration forces students to perform simultaneously, converting extraneous cognitive load into germane processing available for motor schema formation. The experimental group's post-test aerobic skill SD (3.68 vs. pre-test 7.59 and control post-

test 6.77) provides clear distributional evidence of this mechanism—a convergence toward uniformly adequate performance that conventional large-class formats structurally cannot produce.

For the ICREE 2026 conference theme, these findings carry a clear and actionable message: digital pedagogy produces meaningful educational gains not through technological novelty, but through structural redesign. The flipped classroom succeeded because pre-class videos freed in-class time for the peer coaching and corrective feedback that skill acquisition requires, while simultaneously imposing the self-regulatory cycle that metacognitive development needs. This distinction—between technology as content delivery and technology as structural enabler—is the most important insight for educators navigating the AI and digitalization era: the question is not which digital tool to adopt, but how to redesign the temporal architecture of learning so that digital resources activate rather than replace the human interaction that deep learning demands.

VII. CONCLUSION

This study provides the first large-sample quasi-experimental evidence that a structured 16-week flipped classroom intervention significantly enhances learning motivation (d = 0.45), self-directed learning ability (d = 0.77), and aerobic skill performance (d = 0.41) in Chinese university physical education. All three posttest null hypotheses were rejected. The pattern of effect sizes matched theoretical predictions derived from Constructivist Learning Theory, Self-Regulated Learning Theory, and Cognitive Load Theory—constituting not only a demonstration of effectiveness but a mechanistic account of why and through which pathways the model produces its effects. Logistic regression analyses confirmed that these effects represented fundamental distributional shifts: experimental students were dramatically more likely to achieve high performance and less likely to remain in persistently poor outcome categories, reflecting the model's equity-oriented distributional impact.

For practitioners, three design principles emerge as essential and non-negotiable for realising these gains. First, pre-class materials must activate prior movement schemas through guided observation tasks and enforce engagement accountability through quiz thresholds—not merely provide watchable demonstrations. Second, in-class time must be genuinely restructured around ZPD-targeted peer coaching with structured observation protocols, not whole-class re-demonstration. Third, post-class reflection must complete the SRL cycle with criterion-referenced prompts, not open-ended journalling. These principles are achievable within existing class hours and without specialist facilities, making the flipped classroom a scalable, evidence-supported pathway for physical education reform across the diverse landscape of Chinese higher education. Future research should replicate these findings across multiple institutions, examine gender-stratified response patterns, incorporate learning analytics to measure pre-class engagement quality directly, and test whether self-directed learning gains mediate the relationship between instructional format and aerobic skill outcomes through longitudinal mediation designs.

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