

A Systematic Review of the Application of Flow Theory in Educational Research

Dong Xiaojing¹, Hamidah Mohamad² and Cheok Mui Yee³

Universiti Tun Abdul Razak

Dong.xiaojing@ur.unirazak.edu.my

Abstract

This paper systematically reviews flow theory, which describes the optimal immersive learning state and underpins research on intrinsic motivation and deep learning. Against the digital education transformation, the theory has been widely applied in diverse educational contexts. Based on bibliometric and literature analysis, this study sorts global educational flow research into three evolutionary stages and summarizes its core research topics. It further highlights major limitations of existing studies regarding theoretical localization, research methodology, negative-flow exploration and instructional practice. Finally, it proposes future research directions in theoretical innovation, methodological renewal, thematic expansion and practical application, providing references for intelligent immersive teaching and learning.

Keywords: Flow Theory; Learning Immersion; Deep Learning; Intrinsic Learning Motivation; Systematic Review

1. INTRODUCTION

1.1 Research Background and Problem Formulation

Contemporary education is beset by pervasive practical pedagogical challenges, including routine superficial surface learning, chronic attentional fragmentation, learners' disproportionate dependence on extrinsic rewards, and widespread academic burnout (Maslach & Leiter, 2016; Winne & Nesbit, 2010). Against this backdrop, flow theory delivers unique theoretical explanatory power by constructing a coherent causal pathway connecting instructional environmental design, learners' subjective psychological experience and measurable learning performance, a logical architecture that closely aligns with the learner-centred instructional paradigm central to modern curriculum reform agendas (Nakamura & Csikszentmihalyi, 2002; Shernoff et al., 2003). The rapid proliferation of digital learning technologies has introduced further complexity to this research domain: immersive VR/AR laboratories, adaptive AI learning platforms and fragmented short-video learning ecosystems generate novel mechanisms for inducing optimal flow states, yet concurrently cultivate problematic addictive negative flow that undermines sustained academic engagement (Chen et al., 2023; Ye et al., 2026). Nevertheless, existing domestic scholarship exhibits notable structural limitations: available narrative and systematic reviews tend to centre narrowly on isolated academic disciplines or single digital technology contexts, while comprehensive syntheses spanning all educational stages and learner cohorts remain scarce; critical interrogation of unresolved theoretical tensions alongside systematic evaluation of pervasive methodological weaknesses within flow research are also largely absent from prior domestic overviews (Jiang et al., 2021; Wang & Liu, 2022).

1.2 Research Significance

1.2.1 Theoretical Contributions

First, this research advances the theoretical boundary of flow theory by reconciling classical Western flow frameworks with the distinctive indigenous pedagogical contexts prevalent in Chinese higher education, including collectivist classroom norms and exam-centered evaluation mechanisms. Such theoretical integration constructs a holistic pedagogical analytical framework that contextualizes flow experience within localized instructional landscapes, addressing the dearth of culturally embedded flow models in existing cross-cultural scholarship (Li & Zhang, 2024).

Second, the present study systematically synthesizes two decades of cumulative empirical evidence concerning educational flow, harmonizing inconsistent empirical conclusions and reaching unified consensus on the mediating, moderating, and serial multiple mediating mechanisms that govern learners' flow states across diverse instructional environments. This meta-synthetic analysis clarifies ambiguous nomological relationships that have long fragmented prior flow-related empirical inquiries (Chen et al., 2023).

Third, this work pinpoints three underdeveloped theoretical voids within immersive learning research, namely the understudied construct of negative flow, the dynamic evolutionary trajectories of flow throughout prolonged learning cycles, and the scarcity of culturally localized flow measurement scales. By elaborating these unaddressed research gaps, the study substantially expands and refines the integrated theoretical architecture of immersive learning theory (Wang et al., 2025).

1.2.2 Practical Implications

To begin, the research yields differentiated, discipline-tailored instructional design roadmaps rooted in the nine core dimensions of flow experience, which deliver actionable operational guidance for frontline educators seeking to foster sustained immersive engagement among students. The stratified strategies accommodate heterogeneous learning demands across liberal arts, science, engineering and medical disciplines, resolving the one-size-fits-all limitation of generic flow teaching guidelines (Huang & Liu, 2024).

Furthermore, this paper establishes standardized interaction design benchmarks oriented toward facilitating flow states, which can be adopted by developers of intelligent education platforms, virtual simulation curricula and open-access online learning resources. The proposed criteria balance cognitive load regulation and intrinsic motivation stimulation to optimize digital learning interface and activity design (Zhou et al., 2023).

Lastly, the empirical psychological evidence generated herein furnishes decision-making support for university educational administrators to revise classroom evaluation rubrics, restructure after-school homework arrangements and refine institutional governance regimes for blended hybrid teaching, ultimately constructing classroom ecosystems conducive to sustained learner immersion (Wu, 2025).

1.3 Critical Review of Domestic and International Literature

Foundational Phase (1975–1999) is primary theoretical construction, preliminary verification of flow phenomena within classroom, artistic and physical education settings, dominated by qualitative

interviews and Experience Sampling Method (ESM). Quantitative Development Phase (2000–2018) is Standardised flow scales developed; extensive Structural Equation Modelling (SEM) used to test the antecedent “skill-challenge balance”; research expanded into online learning and educational game contexts. Cutting-edge Innovation Phase (2019–present) is integration with educational neuroscience, eye-tracking, electroencephalography physiological measurement, meta-analysis and longitudinal tracking; scholarship centres on flow thresholds and adverse effects of over-immersion within AI and metaverse learning environments. Core characteristics is mature theoretical models, standardised measurement tools, abundant cross-disciplinary experimental designs, and balanced discussions of both positive and negative dualistic flow.

1.4 Research Logic, Scope and Methodology

1.4.1 Literature Search Scope

To ensure comprehensive coverage of domestic and international scholarship on flow theory in education, four authoritative literature databases were selected for document retrieval, Web of Science, CNKI, ERIC and SpringerLink (Liu & Chen, 2023). The search keywords combined core theoretical and contextual terms, including flow, learning immersion, classroom teaching, online learning and educational technology, with a publication timespan set from 1975 to 2026 to capture foundational and cutting-edge studies (Chen, 2006). Rigorous inclusion and exclusion criteria were predefined to enhance screening transparency (Page et al., 2021). Only peer-reviewed empirical investigations, theoretical discussions and systematic reviews within pedagogy, educational psychology and educational technology were retained; publications centred on consumer behaviour, sports training and industrial human–computer interaction were eliminated as irrelevant to educational learning contexts.

1.4.2 Research Methodologies

Three complementary analytical approaches were adopted to synthesise and critique existing literature. First, a standardised systematic review was carried out, with all stages of literature retrieval, duplicate removal, abstract/full-text screening, data coding and thematic synthesis implemented following the PRISMA 2020 reporting protocol to guarantee reproducibility and methodological transparency (Page et al., 2021). Second, bibliometric analysis via CiteSpace visualisation software was utilised to map keyword co-occurrence clustering, temporal research evolution trajectories and author co-citation networks, enabling quantitative identification of research hotspots and disciplinary knowledge linkages (Chen, 2006; Yang & Fang, 2024). Third, inductive and deductive reasoning was applied to integrate consistent empirical conclusions from prior studies, systematically critique pervasive theoretical and methodological limitations in current flow research, and deduce targeted directions for future scholarly exploration (Booth et al., 2016).

2. THE ORIGINS, CORE STRUCTURE AND PEDAGOGICAL COMPATIBILITY LOGIC OF FLOW THEORY

2.1 Theoretical Origins and Conceptual Definition of Flow

The construct of flow originates from Mihaly Csikszentmihalyi’s decades-long qualitative inquiries into optimal subjective experience, a line of research departing sharply from behaviourist and psychoanalytic paradigms that dominated mid-twentieth-century psychological scholarship

(Nakamura & Csikszentmihalyi, 2002). Dissatisfied with frameworks that prioritised pathology over human flourishing, Csikszentmihalyi conducted open-ended interviews with artists, athletes and students engaged in deep, rewarding activity, identifying a recurring phenomenological state marked by unbroken concentration and intrinsic reward; these preliminary observations formed the empirical foundation for his 1975 monograph *Beyond Boredom and Anxiety*, which formally conceptualised flow as a discrete psychological condition distinct from boredom, anxiety and routine satisfaction (Csikszentmihalyi, 1975).

Decades of subsequent refinement have stabilised a consensus definition within educational psychology: flow describes a holistic, autotelic experience that emerges when individuals engage with a task whose challenges align closely with their existing skill repertoire, characterised by seamless integration of awareness and action alongside diminished self-referential rumination (Shernoff et al., 2003). Crucially, the autotelic nature of flow differentiates it from transient engagement driven by external incentives—a distinction of central relevance to pedagogical research investigating intrinsic learning motivation (Egbert, 2003). While early work framed flow as a universal human experience observable across all domains of voluntary activity, contemporary educational scholarship has refined this framing to delineate context-specific variants, drawing clear conceptual boundaries between adaptive academic flow, passive digital immersion and addictive pseudo-flow triggered by algorithmic media environments (Chen et al., 2023). Such differentiation addresses a critical oversight in early classroom applications of flow theory, which often conflated superficial task absorption with the deep, cognitively productive flow states that facilitate meaningful learning.

2.2 The Nine Original Flow Attributes and Three-Dimensional Pedagogical Deconstruction

In his foundational theoretical elaboration, Csikszentmihalyi (1990) delineated nine interrelated experiential markers that collectively constitute complete flow episodes, marking the universal phenomenological benchmarks for identifying optimal human experience. These nine core attributes include unambiguous proximal goals, immediate and actionable task feedback, a balanced match between personal skill and situational challenge, full concentration restricted to task-relevant stimuli, seamless fusion of awareness and behavioural action, temporary suppression of self-conscious rumination, distorted subjective perception of time, a robust sense of personal control over ongoing activities, and intrinsic autotelic reward derived purely from task engagement itself (Nakamura & Csikszentmihalyi, 2002). As a holistic experiential construct, these nine dimensions cannot be treated as isolated indicators; the simultaneous coexistence of most features distinguishes genuine flow from shallow task engagement or passive entertainment immersion, a distinction frequently overlooked in early classroom-based empirical work (Shernoff et al., 2003).

Despite the universality of the nine-factor framework, raw unadopted flow taxonomy lacks targeted explanatory power for formal learning contexts, which operate within structured curricular arrangements, staged knowledge acquisition and institutional assessment systems. To resolve this mismatch, educational psychologists have reorganised the nine inherent attributes into a context-specific three-layer analytical framework tailored exclusively to classroom learning scenarios, partitioning flow mechanisms into conditional prerequisites, real-time experiential processes, and long-term learning outcomes (Wang & Liu, 2022). The conditional layer encapsulates the preconditions required to trigger learning flow, consolidating clear task objectives, timely formative feedback, and the skill-challenge equilibrium—three controllable variables directly manipulable via instructional design. The process layer captures the subjective psychological shifts unfolding while learners remain immersed in academic tasks, encompassing sustained focused attention, transient

loss of self-awareness, and altered temporal perception. The outcome layer addresses the durable educational gains produced by flow engagement, centred on heightened intrinsic motivation, sustained affective enjoyment during study, persistent voluntary learning willingness, and deep knowledge construction rather than surface-level memorisation (Chen et al., 2023).

This tripartite pedagogical reclassification delivers two distinct scholarly merits for educational research. First, it transforms abstract psychological descriptors into operable instructional variables, allowing curriculum designers and educational technologists to intervene at specific generative stages of flow. Second, it establishes a clear analytical boundary between environmental design inputs, learner internal states, and measurable academic outputs, laying a structured theoretical foundation for subsequent quantitative modelling of mediating and moderating effects within flow learning chains (Hamari & Keronen, 2017).

2.3 Inherent Logic Underpinning Flow Theory's Compatibility with Educational Research

The alignment between flow theory and educational inquiry is not merely superficial; it stems from fundamental overlaps between the structural prerequisites of autotelic experience and the core organisational logic of formal learning activities, a correspondence widely recognised by scholars of educational psychology and instructional design (Shernoff et al., 2003). All structured learning tasks, whether classroom coursework, laboratory practice or digital self-directed study, possess three defining properties that satisfy the foundational conditions required to trigger flow states, as originally outlined by Csikszentmihalyi (1990): clearly defined incremental objectives, iterative feedback loops built into assessment and task progression, and adjustable levels of cognitive or practical challenge that can be matched to learners' evolving skill sets. Unlike passive recreational activities that only occasionally meet these criteria, teaching and learning are intentionally structured around goal-setting, formative evaluation and differentiated task difficulty, making educational contexts uniquely fertile ground for cultivating sustained flow (Egbert, 2003).

Beyond structural congruence at the task level, flow's emphasis on intrinsic reward addresses a longstanding theoretical and practical limitation within mainstream pedagogy: the overreliance on external incentives such as grades, prizes and teacher praise to drive student participation (Nakamura & Csikszentmihalyi, 2002). Decades of motivational research confirm that learning sustained solely through extrinsic reinforcement often yields superficial memorisation, heightened test anxiety and rapid disengagement once external rewards are removed (Maslach & Leiter, 2016). Flow's autotelic mechanism resolves this tension by locating motivational force within the act of learning itself. When students enter flow, engagement is self-sustaining, reducing dependence on external regulatory stimuli and fostering the deep, voluntary cognitive investment central to deep learning paradigms (Chen et al., 2023). This unique explanatory power renders flow an indispensable analytical tool for research targeting the mitigation of academic burnout and surface-level study habits.

Most critically, the three-tier pedagogical reorganisation of flow's nine attributes establishes a cohesive analytical chain that maps neatly onto the full scope of educational research practice (Wang & Liu, 2022). The conditional dimension of flow corresponds to instructional and environmental design variables controllable by educators and curriculum developers; the process dimension captures real-time subjective learning experience, a core focus of educational emotion and engagement scholarship; the outcome dimension links immersive psychological states to measurable academic indicators including knowledge retention, creative thinking and long-term learning

persistence. This end-to-end logical chain enables researchers to construct integrated conceptual models that trace causal pathways from classroom intervention design to learner psychological experience and final learning performance, filling a gap left by fragmented motivational or cognitive theories that only explain isolated segments of the learning process (Hamari & Keronen, 2017). For this reason, contemporary systematic reviews of immersive learning consistently position flow theory as a unifying framework capable of bridging instructional practice, learner psychology and learning outcome measurement across all educational stages and disciplinary contexts.

3. TEMPORAL EVOLUTION OF INTERNATIONAL AND DOMESTIC FLOW RESEARCH WITHIN EDUCATION

3.1 Theoretical Introduction and Phenomenon Verification Phase

During this initial developmental window of educational flow research, qualitative methodologies dominated international empirical work, with early scholarship confined primarily to phenomenological observation and descriptive validation of flow episodes within classroom contexts (Boyer & Lamoreaux, 1997; Shernoff et al., 2003). Most foundational studies only confirmed that optimal experiential states could be observed among student cohorts, yet lacked rigorous quantitative modelling to unpack the mediating and moderating mechanisms that govern flow generation amid formal learning tasks (Egbert, 2003). Without validated domain-specific measurement instruments, researchers in this era could not systematically quantify the interplay between task challenge, learner skill and subjective immersion, restricting analytical depth to surface-level descriptive accounts rather than testable causal frameworks (Jackson & Marsh, 1996).

3.2 Model Construction and Cross-Sectional Empirical Phase

This intermediate developmental stage marked a definitive methodological shift away from descriptive qualitative observation toward quantitative causal modelling, as validated domain-specific flow measurement instruments became widely accessible to educational researchers globally (Jackson & Marsh, 1996; Shernoff et al., 2003). International scholarship prioritised the construction of integrated conceptual frameworks linking environmental instructional antecedents, state flow experience and distal academic outcomes, deploying cross-sectional questionnaire designs paired with structural equation modelling (SEM) to systematically test mediating and moderating pathways between skill-challenge equilibrium and learning performance (Hamari & Keronen, 2017; Venkatesh et al., 2012). Empirical inquiry expanded beyond conventional in-person classroom contexts to encompass early online learning platforms and educational games, enabling systematic comparison of flow generation mechanisms across analogue and digital learning environments (Barzilai & Blau, 2014). Despite robust advances in model specification, nearly all international work within this window relied on one-off snapshot cross-sectional datasets, a methodological constraint that prohibited definitive causal inference and restricted scholars to reporting correlational relationships rather than tracking dynamic shifts in flow over time (Van der Linden et al., 2021).

3.3 Digital-Intelligent Empowerment and Multi-Method Innovation Phase

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4.FOUR CORE THEMATIC CLUSTERS OF FLOW THEORY RESEARCH IN EDUCATION

4.1 Antecedents and Generative Mechanisms of Learning Flow

A dominant strand within global flow scholarship centres on unpacking multi-layered antecedent configurations and their sequential causal pathways that give rise to immersive learning flow, representing the most heavily investigated research agenda across quantitative educational psychology and educational technology publications (Hamari & Keronen, 2017; Wang & Liu, 2022). Extant empirical evidence stratifies predictive factors into three mutually interactive levels: individual learner attributes, classroom instructional arrangements, and digital platform environmental characteristics, each exerting unique direct and conditional effects on the likelihood of flow emergence (Shernoff et al., 2003).

At the individual learner level, stable dispositional traits and state-based academic emotions constitute foundational personal precursors. Extensive cross-sectional and limited longitudinal evidence confirms academic self-efficacy, intrinsic learning interest, sustained attentional control and adaptive academic emotion as robust positive predictors of flow, while test anxiety and academic self-doubt consistently suppress immersive states (Van der Linden et al., 2021). Learners' digital literacy has additionally emerged as a salient individual predictor within technology-mediated learning contexts, governing their capacity to navigate platform interfaces and maintain unbroken task focus without extraneous cognitive distraction (Chen et al., 2023).

At the instructional environment layer, curriculum and classroom design variables operate as controllable situational triggers of flow. Graded hierarchical task scaffolding, transparent segmented learning goals, and continuous formative feedback systems jointly establish the skill-challenge balance central to flow generation (Egbert, 2003). Interactive classroom dialogue, differentiated task allocation and real-time formative assessment further amplify immersive experience by aligning task complexity with fluctuating learner proficiency throughout teaching sequences (Bressler & Bodzin, 2013).

Within digital technology ecosystem contexts, interface usability, cross-device compatibility, instantaneous interactive feedback speed, and algorithmic adaptive matching of resource difficulty function as technology-specific antecedents shaping online and virtual learning flow (Barzilai & Blau, 2014). Cumulative meta-analytic findings consolidate a consensus on core generative mechanisms: skill-challenge equilibrium and timely actionable feedback operate as the two strongest positive direct predictors of flow, while flow itself consistently functions as a significant mediating variable

transmitting the effects of environmental and individual antecedents onto distal learning outcomes (Hamari & Keronen, 2017). Despite well-established linear mediating pathways, few studies adopt configurational analytical approaches such as fuzzy-set qualitative comparative analysis to unpack how combinations of multiple precursors jointly produce high-flow learning episodes, leaving configurational interaction effects underexplored within existing literature.

4.2 Associations Between Flow Experience and Diverse Learning Outcomes

A substantial body of quantitative educational psychology research has sought to quantify the predictive linkages between state flow immersion and an array of cognitive, affective, behavioural and performance-based learning outcomes, forming one of the most mature subfields within flow theory scholarship (Hamari & Keronen, 2017; Van der Linden et al., 2021). Cumulative cross-sectional, longitudinal and quasi-experimental evidence establishes consistent positive associations between sustained learning flow and a spectrum of desirable academic endpoints, alongside inhibitory effects on maladaptive learning states, though recent digital education research has surfaced nuanced contradictory findings regarding excessive prolonged

immersion (Chen et al., 2023).

In terms of adaptive cognitive and behavioural learning outputs, immersive flow states robustly predict deep knowledge processing, long-term knowledge retention, formal academic attainment, self-reported learning satisfaction, persistent voluntary learning intention and creative problem-solving performance across K-12, higher and vocational education cohorts (Shernoff et al., 2003). Learners reporting frequent flow episodes demonstrate heightened in-class participation, greater willingness to undertake extended independent study and stronger autonomous self-regulation, as the autotelic reward intrinsic to flow decouples academic engagement from external regulatory pressures such as grading or teacher surveillance (Nakamura & Csikszentmihalyi, 2002). Game-based and virtual simulation learning research further corroborates this pattern: when digital tasks successfully induce balanced flow, participants exhibit superior transfer of procedural knowledge to real-world practical assessments (Barzilai & Blau, 2014).

Flow also functions as a protective psychological buffer against adverse academic affective states. Meta-analytic syntheses confirm that consistent flow engagement significantly mitigates test anxiety, attenuates chronic learning burnout and reduces classroom inattention and mind-wandering (Maslach & Leiter, 2016; Wang & Liu, 2022). By anchoring learner attention to task-specific goals and generating intrinsic satisfaction, flow interrupts the self-reinforcing cycle of disengagement, negative academic self-evaluation and emotional exhaustion that characterises chronic student burnout.

Notwithstanding the widely documented beneficial outcomes of moderate, well-calibrated flow, contemporary digital education studies have identified a critical boundary condition frequently overlooked in earlier cross-sectional research: extreme, unregulated over-immersion carries distinct adverse academic consequences (Chen et al., 2023). Extended uninterrupted flow within algorithm-driven short-video platforms or repetitive digital drill software may induce cognitive depletion, fragmented knowledge construction and technology-dependent pseudo-immersion that resembles flow yet fails to support deep learning; a subset of longitudinal data even links unmoderated digital flow to compulsive screen use and delayed academic procrastination. This contradictory empirical evidence reveals a critical unresolved tension within the literature, whereby linear positive correlations dominate static cross-sectional analysis, yet nonlinear threshold effects emerge when

tracking learning experiences over extended timeframes. Such inconsistency highlights the limitations of conventional snapshot survey designs, which cannot capture the dose-dependent dual effects of flow on learning performance.

4.3 Instructional Design and Curriculum Modelling Informed by Flow Theory

A distinct applied research stream translates the theoretical tenets of flow into operable curriculum architectures and classroom design protocols, bridging psychological theory and pedagogical practice across general, discipline-specific and technology-mediated learning contexts. Unlike correlational mechanism research focused on variable relationships, this body of scholarship adopts design-based research and intervention frameworks to develop replicable instructional blueprints calibrated to trigger sustained academic flow (Bressler & Bodzin, 2013; Wang et al., 2014). Three interrelated strands dominate this applied thematic cluster: universal classroom flow design templates, discipline-tailored curriculum models, and digital learning frameworks optimised for immersive experience.

4.3.1 Generalised Flow-Oriented Instructional Frameworks for Conventional Classrooms

Scholars focusing on universal K-12 and undergraduate classroom practice have proposed a modular design logic centred on three controllable flow preconditions delineated by Csikszentmihalyi (1990): aligned skill-challenge balance, transparent proximal objectives, and continuous formative feedback. The resulting generic framework structures learning activities around hierarchically scaffolded gradient tasks, partitioned sequential micro-goals, and embedded in-situ feedback loops accessible during task completion (Shernoff et al., 2003). Hierarchical gradient task sequencing ensures incremental difficulty progression matched to heterogeneous learner proficiency, while segmented micro-goals decompose overarching unit targets into small, achievable milestones that deliver frequent minor success signals. Real-time classroom feedback mechanisms—including peer formative assessment, instantaneous teacher verbal prompts, and brief formative quizzes—eliminate delayed evaluative lag, a well-documented barrier to uninterrupted flow episodes in traditional lecture-dominated teaching (Egbert, 2003). This tripartite generic architecture provides a transferable baseline template adaptable to most conventional classroom environments, independent of disciplinary subject boundaries.

4.3.2 Discipline-Specialised Flow Curriculum Models

Flow's experiential dynamics manifest uniquely across subject domains due to divergent cognitive and motor learning demands, prompting scholars to refine universal frameworks into discipline-specific curriculum models tailored to domain-specific learning mechanisms. For foreign language education, immersive reading and writing pedagogies prioritise context-rich communicative tasks that align linguistic complexity with learners' vocabulary and grammatical proficiency to sustain linguistic flow throughout text production and comprehension (Egbert, 2003). Within science and engineering education, laboratory experimental teaching models embed iterative inquiry cycles and hands-on operational challenges, balancing theoretical conceptual skill with hands-on technical challenge to generate flow during experimental design and data analysis (Zhou & Pan, 2025). Arts education adopts aesthetic classroom frameworks centred on creative expressive tasks with flexible difficulty calibration, leveraging the autotelic reward inherent to artistic creation to cultivate sustained immersive engagement. Physical education and motor skill training build flow-centred motor learning sequences, where progressive motor challenge and immediate kinesthetic feedback

reduce self-consciousness and facilitate uninterrupted skill practice (Li, 2021). Collectively, these domain-specific adaptations demonstrate that generic flow design principles require disciplinary customisation to accommodate distinct cognitive, linguistic, manipulative and motor learning logics.

4.3.3 Flow-Centred Design Architectures for Digital and Blended Curricula

Against the backdrop of educational digitalisation, a growing corpus of design research constructs integrated flow-oriented frameworks for technology-mediated learning scenarios, encompassing educational serious games, virtual simulation laboratories, and synchronous-asynchronous hybrid teaching ecosystems. For educational game design, scholars anchor interactive mechanics to flow's core prerequisites by embedding tiered challenge progression, instant performance feedback, and clear mission objectives within game narratives (Barzilai & Blau, 2014). Virtual simulation curriculum models further optimise digital flow by adjusting task complexity in response to real-time learner operational performance within immersive virtual environments, minimising cognitive friction that disrupts sustained immersion (Wang & Liu, 2022). Hybrid online-offline integrated teaching frameworks combine offline scaffolded face-to-face task guidance with adaptive online digital resources, coordinating in-class feedback and asynchronous digital formative evaluation to maintain consistent flow states across segmented blended learning sessions (Chen et al., 2023). Unlike static offline classroom frameworks, these digital curriculum models additionally address technology-specific barriers to flow, such as cumbersome interface navigation and mismatched resource difficulty, forming context-specific design criteria exclusive to smart learning ecosystems.

4.4 Comparative Analysis of Heterogeneous Flow Dynamics Across Segmented Educational Learning Contexts

A substantial subset of applied flow scholarship undertakes cross-context comparative analysis to unpack how institutional structures, learner demographics, task characteristics and delivery modalities reshape the formation, intensity and sustainability of flow experience across distinct educational segments. Rather than treating learning flow as a uniform psychological state invariant to contextual conditions, this body of literature documents systematic disparities in flow triggers, maintenance mechanisms and associated learning benefits between basic, higher, vocational and niche specialist education environments (Jiang et al., 2021; Wang & Liu, 2022). Such comparative work addresses a key limitation of early flow research, which often generalised findings derived from single cohorts or narrow learning scenarios without cross-context validation. Four dominant contextual clusters have emerged within the extant empirical literature.

4.4.1 Basic Education Settings

Research situated within primary and secondary education predominantly examines flow generation within standard teacher-led classroom instruction, extended learning provision and tiered homework arrangements tailored to mixed-ability student cohorts. Within compulsory schooling, fixed curriculum frameworks, age-based cognitive constraints and whole-class collective teaching formats create unique boundary conditions for flow: uniform pacing and one-size-fits-all assignments frequently disrupt the critical skill-challenge balance required to sustain immersive states (Shernoff et al., 2003). Extended after-school learning and stratified homework design emerge as viable remedial design solutions; tiered task difficulty allows educators to align academic challenge with individual student proficiency, generating more consistent flow episodes than standardised whole-class worksheets (Zhang et al., 2023). Notably, flow in basic education exhibits

greater volatility than in post-compulsory settings, as younger learners possess limited self-regulatory capacity to recover flow once external classroom distractions break concentration (Van der Linden et al., 2021).

4.4.2 Higher Education Settings

Undergraduate and postgraduate learning environments feature autonomous study schedules, domain-specialised knowledge content and diverse digital laboratory infrastructure, producing markedly different flow profiles compared with K-12 cohorts. Specialist disciplinary coursework relies on complex abstract reasoning and self-directed inquiry, where sustained flow is closely tied to students' intrinsic disciplinary interest and autonomous task selection (Chen et al., 2023). Innovation and entrepreneurship curricula prioritise open-ended creative problem-solving, whose flexible, non-standardised task parameters offer greater scope for autotelic engagement than rigid lecture-based instruction (Huang & Ye, 2025). Virtual simulation laboratories deliver immersive digital task environments that amplify flow through real-time operational feedback and interactive visualisation, yet risk generating superficial pseudo-flow if simulation tasks lack sufficient cognitive depth (Wang & Liu, 2022). Foreign language literacy training at tertiary level forms a distinct substream of inquiry, where communicative task complexity and immediate linguistic feedback

operate as primary catalysts for linguistic flow (Egbert, 2003).

4.4.3 Vocational Education Settings

Vocational education flow research centres on skill-based practical training and digital vocational simulation systems, where psychomotor operation and procedural task mastery become the core drivers of immersive experience. Unlike academic classroom flow rooted in abstract cognitive processing, vocational flow hinges on incremental mastery of operational routines, kinesthetic feedback and visible tangible task outcomes (Wang & Liu, 2020). Digitised training platforms further optimise flow by modularising skill challenges and embedding instantaneous performance scoring, though mismatches between digital simulation difficulty and trainees' foundational practical competence readily induce disengagement or overwhelming anxiety (Guo, 2019). Compared with general academic learning contexts, vocational flow exhibits stronger associations with sustained occupational learning intention and practical skill retention, given the direct alignment between immersive task practice and workplace competency requirements.

4.4.4 Niche Specialised Learning Contexts

A smaller yet fast-growing body of literature investigates flow dynamics within understudied niche educational populations and emerging technology-mediated learning ecosystems. Special education research documents modified flow preconditions for neurodiverse and disabled learners, requiring adjusted task pacing, simplified multi-stage micro-goals and sensory-friendly feedback mechanisms to mitigate cognitive overload (Wang & Liu, 2022). Adult continuing education caters to mature learners with fragmented study time, competing occupational responsibilities and heterogeneous prior knowledge bases; their flow episodes are shorter, more easily disrupted and heavily dependent on task relevance to personal career objectives (Jiang et al., 2021). Most recently, AI-adaptive online learning platforms represent an emergent digital context, where algorithmic real-time adjustment of task complexity theoretically stabilises skill-challenge equilibrium, yet over-automated repetitive drill tasks risk generating hollow pseudo-flow disconnected from deep knowledge construction

(Chen et al., 2023). Comparative cross-context evidence confirms that adaptive artificial intelligence systems simultaneously introduce novel flow-supporting design opportunities and previously unobserved risks of superficial digital immersion absent from traditional offline learning environments.

5.CORE LIMITATIONS AND UNRESOLVED THEORETICAL TENSIONS IN CONTEMPORARY PEDAGOGICAL FLOW SCHOLARSHIP

5.1 Deficits in Contextualised Theoretical Construction

A foundational theoretical constraint permeating domestic flow research lies in the wholesale transplantation of Western theoretical architectures without systematic cultural recalibration, alongside persistent gaps in conceptual frameworks tailored to China's unique institutional and classroom ecology (Jiang et al., 2021). Three interrelated theoretical shortcomings dominate this domain of critique.

5.1.1 Unreflective Adoption of Measurement Instruments and Conceptual Models

Most Chinese empirical investigations directly deploy flow scales and structural models validated within Western individualistic educational contexts, with minimal psychometric refinement to accommodate indigenous classroom realities (Wang et al., 2014). Flow theory originates from autonomous, self-directed individual activities such as artistic creation and solitary laboratory practice, which diverge sharply from China's dominant collective whole-class instruction, exam-centred assessment systems, and mixed-ability stratified student cohorts (Xu & Zhao, 2024). When unmodified Western measurement tools are applied to local student samples, survey items fail to capture culturally distinctive situational triggers of flow, including collective peer task collaboration, grade-driven goal pursuit and teacher-led synchronous learning, introducing systematic construct bias that undermines the validity of resulting statistical inferences (Chen et al., 2023). Few studies conduct rigorous cross-cultural measurement invariance testing to revise scale dimensions for Chinese K-12 and university learner populations, perpetuating a one-size-fits-all theoretical importation paradigm.

5.1.2 Lack of Distinct Conceptual Frameworks for Collective Classroom Flow

Virtually all canonical Western flow literature conceptualises optimal experience as an individual-level psychological construct generated through solitary personal engagement (Nakamura & Csikszentmihalyi, 2002). This individual-centred theoretical lens cannot fully explain group-based immersive states emerging within China's collective classroom settings, where synchronous task participation, shared group goals and peer interaction jointly shape unified class-wide engagement dynamics (Jiang et al., 2021). To date, few scholars have developed bespoke theoretical typologies to differentiate discrete individual flow episodes from collective classroom flow, nor have they delineated the unique environmental and social antecedents that facilitate group immersive learning. This theoretical blind spot means existing models overlook interdependent social mechanisms central to Chinese collective teaching, restricting the explanatory power of flow theory within local pedagogical research.

5.1.3 Underexplored Theoretical Boundaries

Extant domestic flow scholarship overwhelmingly prioritises the adaptive, beneficial dimensions of moderate immersive engagement, while theoretical discussion addressing flow's adverse experiential boundaries remains fragmentary and underdeveloped (Chen et al., 2023). International digital education research has empirically documented nonlinear flow effects: excessive unregulated immersion triggers cognitive exhaustion, attentional depletion and pseudo-flow states that mimic optimal experience yet fails to facilitate deep knowledge acquisition (Wang & Liu, 2022). Despite these global empirical warnings, few domestic theoretical works construct systematic boundary frameworks to define critical flow intensity thresholds, distinguish productive adaptive flow from maladaptive addictive over-immersion, or unpack the cognitive and affective mechanisms linking prolonged unbroken flow to academic fatigue. This theoretical vacuum creates an incomplete, one-sided understanding of flow's dualistic impacts and hinders the design of balanced instructional interventions that cultivate immersive learning without inducing learner burnout.

5.2 Limitations in Research Methodological Design

Methodological rigidity constitutes a second systemic limitation visible across existing pedagogical flow inquiries, as the vast majority of empirical work adheres to static cross-sectional quantitative protocols while neglecting multi-temporal, multimodal and mixed-method designs capable of capturing the fluid, context-dependent nature of learning flow (Van der Linden et al., 2021). Three interlocking methodological deficits hinder the robustness and ecological validity of current empirical findings.

5.2.1 Overdependence on Cross-Sectional Self-Report Surveys and Underutilisation of Longitudinal and Interventional Designs

Cross-sectional questionnaire sampling represents the dominant data collection strategy within domestic and much international flow research, yet such one-off snapshot measurements can only capture static correlational relationships rather than unpack directional causal trajectories or within-person temporal variability of immersive states (Blume et al., 2022). Longitudinal multi-wave tracking designs, daily Experience Sampling Method (ESM) and controlled quasi-experimental intervention trials remain remarkably scarce within educational flow scholarship. ESM, in particular, enables repeated real-time capture of flow fluctuations across daily classroom sessions, resolving the recall bias embedded in retrospective survey responses (Fullagar & Kelloway, 2009). Quasi-experimental manipulations, by contrast, allow researchers to isolate how targeted instructional adjustments reshape learners' flow intensity; without such longitudinal and interventional frameworks, existing literature struggles to differentiate stable dispositional flow tendencies from transient situational immersion triggered by specific classroom tasks.

5.2.2 Scarcity of Objective Physiological and Behavioural Metrics, Resulting in Systematic Self-Report Response Bias

Nearly all prevailing empirical evidence relies exclusively on subjective self-reported flow scales, with few studies integrating objective multimodal physiological and behavioural indicators to triangulate self-perceived immersion (Wang & Liu, 2022). Contemporary educational neuroscience and learning analytics research have validated eye-tracking, electroencephalography (EEG) and classroom behavioural big data as complementary objective proxies for sustained attentional engagement and flow onset: consistent fixation patterns, reduced saccadic distraction and stable neural activation signatures correspond reliably to high-flow episodes (Chen et al., 2023). The near-total absence of

such objective measurement tools creates mono-source response bias, wherein learner self-evaluations are vulnerable to social desirability effects, retrospective memory distortion and inconsistent personal interpretation of flow scale items. This singular reliance on subjective data weakens the convergent validity of established flow models.

5.2.3 Marginalisation of Mixed-Method and In-Depth Qualitative Inquiry to Capture Dynamic Flow Episodes

Quantitative mono-method designs far outnumber mixed-method protocols and intensive qualitative investigations within existing flow research portfolios (Bressler & Bodzin, 2013). In-depth semi-structured interviews, classroom ethnography and iterative thematic qualitative coding are rarely deployed to unpack the nuanced, contextually embedded processes through which flow emerges, intensifies or dissipates during extended learning activities. Quantitative surveys quantify aggregate flow levels across participant cohorts but fail to document the moment-by-moment experiential shifts, social peer influences and task-specific triggers that shape individual immersive trajectories. Without balanced mixed-method integration that combines statistical generalisation with contextual qualitative depth, current scholarship lacks fine-grained descriptive accounts of dynamic within-lesson flow volatility, narrowing the granularity of theoretical and practical insights available to instructional designers.

5.3 Research Content

Beyond methodological rigidities, contemporary educational flow research suffers from substantial content homogeneity and thematic stagnation, with most empirical work confined to repetitive hypothesis verification while overlooking emerging boundary phenomena and nuanced conditional mechanisms (Jiang et al., 2021; Wang & Liu, 2022). Such narrow research focus results in incremental rather than paradigm-shifting theoretical progress, restricting the disciplinary depth and practical applicability of existing flow scholarship in digital educational contexts.

5.3.1 Superficial Replication of Linear Correlational Findings and Shortage of Advanced Mechanism Analysis

A pervasive limitation within current literature is the overemphasis on validating the basic linear assumption that learning flow positively predicts academic engagement and performance outcomes (Hamari & Keronen, 2017). Most empirical studies merely replicate rudimentary bivariate correlation or simple mediating effect modelling, resulting in highly homogenised conclusions with limited theoretical contribution (Chen et al., 2023). Advanced analytical approaches capable of unpacking complex educational mechanisms, such as serial multiple mediation modelling and configurational effect analysis, remain severely underutilised. Traditional linear models fail to explain how multiple environmental, individual and technological factors jointly co-configure high-flow learning states, nor can they reveal the chained psychological pathways through which flow evolves across continuous learning sessions (Rosas, 2023). The persistent reliance on simplistic verification designs has led to research saturation, where incremental empirical replication dominates the field while sophisticated mechanism exploration remains scarce.

5.3.2 Insufficient Stratified Comparative Analysis of Heterogeneous Learner Cohorts and Contextual Differences

Existing flow research predominantly adopts a homogenised aggregate analytical perspective, neglecting stratified comparative investigations across differentiated learner groups and educational scenarios (Zito et al., 2025). Empirical evidence has confirmed that flow generation mechanisms are highly sensitive to individual and contextual variations, yet few studies systematically compare discrepancies between urban and rural student cohorts, learners with divergent digital literacy proficiency, and participants across different educational stages and disciplinary domains (Li et al., 2023). For instance, students in under-resourced rural educational settings exhibit distinct flow trigger patterns due to limited digital infrastructure and differentiated instructional environments, while STEM and humanities learners demonstrate divergent cognitive demands that reshape skill-challenge balance dynamics (Xu & Zhao, 2024). The absence of systematic subgroup comparison obscures boundary conditions of flow theory, hindering the development of differentiated instructional strategies tailored for heterogeneous student populations.

5.3.3 Research Gaps in Pseudo-Flow Mechanisms Induced by Fragmented Digital Learning Platforms

With the proliferation of algorithm-driven short-video platforms and automated AI drill systems in modern education, a critical theoretical and empirical gap lies in the exploration of superficial pseudo flow a maladaptive immersive state distinct from authentic learning flow (Chen et al., 2023). Unlike structured classroom tasks that facilitate deep knowledge construction, fragmented short-video browsing and repetitive AI skill drills generate transient, algorithm-induced immersion characterised by low cognitive engagement, passive information reception and illusory learning satisfaction (Wang & Liu, 2022). Although international scholarship has warned of the cognitive exhaustion and learning inertia caused by unregulated digital immersion, domestic educational research has rarely systematically delineated the generative mechanisms, distinguishing features and adverse academic impacts of pseudo-flow. This oversight leads to an incomplete theoretical system that only addresses adaptive optimal flow while ignoring the dark side of digital learning immersion, resulting in one-sided instructional guidance for smart education practice.

5.4 Practical Translation Limitations

In addition to theoretical and methodological deficiencies, extant flow research exhibits prominent translational gaps between theoretical modelling and real-world pedagogical implementation. Most proposed instructional strategies remain conceptual and non-standardised, lacking operable, context-adaptive intervention protocols that can be reliably replicated in routine classroom and smart learning scenarios (Fullagar & Kelloway, 2009; Jiang et al., 2021). These practical deficits weaken the instructional applicability of flow theory and hinder its systematic integration into formal curriculum design, digital platform

development and teacher professional development systems.

5.4.1 Homogenised Instructional Strategies and the Absence of Stratified Standardised Intervention Protocols

Existing pedagogical guidelines for fostering learning flow are predominantly generic and one-size-fits-all, providing broad design principles rather than discipline-specific and stage-differentiated operational protocols (Martin et al., 2023). Most intervention frameworks overlook the heterogeneous cognitive demands, task characteristics and assessment logics that distinguish K-12 foundational education, higher disciplinary training and vocational skill-based instruction (Zito et al.,

2025). Although meta-analytic evidence has confirmed that flow generation mechanisms vary substantially across academic subjects and educational stages, few studies have developed stratified, replicable intervention procedures tailored to different learning contexts (Li et al., 2023). The lack of standardised, graded implementation guidelines results in low practical convertibility: teachers can hardly translate abstract flow principles into actionable lesson arrangements, leading to inconsistent intervention effectiveness in real classrooms.

5.4.2 Lack of Universal Design Criteria for Flow-Oriented Smart Learning Platforms

Against the backdrop of intelligent educational transformation, digital learning platforms have increasingly adopted flow-centred design logic to optimise user experience, yet unified industry-level interactive design standards remain absent (Chen et al., 2023). Current platform optimisation practices rely heavily on developers' empirical experience rather than theoretically validated, research-based design specifications regarding interface layout, feedback timeliness, adaptive difficulty matching and interactive rhythm control (Wang & Liu, 2022). Without universal evaluative and developmental criteria, digital educational products exhibit substantial design heterogeneity: some overemphasise entertaining immersion and induce pseudo-flow, while others fail to deliver timely task feedback, restricting genuine deep-learning flow generation (Hamari & Keronen, 2017). The absence of consensus technical specifications impedes the iterative optimisation and

large-scale promotion of flow-oriented smart learning ecosystems.

5.4.3 Insufficient Supporting Research on Flow-Centred Teacher Training Systems

Effective flow-based classroom intervention depends heavily on teachers' professional capacity for real-time task scaffolding, dynamic difficulty adjustment and affective instructional regulation, yet systematic research on targeted teacher training mechanisms remains severely limited (Bressler & Bodzin, 2013). Existing professional development programmes predominantly focus on general instructional technology skills rather than specialised competencies for identifying flow signals, preventing over-immersion, and calibrating task challenge in response to in-class learning fluctuations (Xu & Zhao, 2024). The scarcity of mature training curricula and systematic competency frameworks means most in-service teachers lack structured guidance to implement flow-oriented pedagogy, forming a critical human-resource bottleneck that restricts the real-world implementation of theoretical outputs (Jiang et al., 2021).

6.FUTURE RESEARCH AGENDA FOR FLOW THEORY IN EDUCATION WITHIN THE DIGITAL-INTELLIGENT ERA

6.1 Theoretical Innovation

Future theoretical advancement in educational flow research should prioritise the systematic construction of indigenous pedagogical models tailored to the socio-cultural and instructional characteristics of Chinese classroom contexts, addressing the longstanding over-reliance on Western theoretical paradigms (Jiang et al., 2021). First, contextually validated indigenous flow measurement instruments need to be developed and psychometrically verified, replacing directly imported Western scales that fail to accommodate culturally specific instructional features, including collective whole-class interaction, stratified student ability grouping, and exam-oriented assessment mechanisms (Xu & Zhao, 2024). Second, subsequent theoretical modelling should explicitly

differentiate individual task flow from class-based collective flow experiences, establishing context-specific generative mechanisms that explain how group-level instructional dynamics shape immersive learning states within collective classroom environments (Chen et al., 2023). Third, to resolve the existing one-sided conceptualisation of flow as universally beneficial, future theorisation must construct a comprehensive three-dimensional boundary framework that distinguishes adaptive positive flow, cognitively exhausting over-immersion, and algorithm-induced addictive pseudo-flow, while empirically defining the optimal threshold ranges that differentiate productive learning immersion from maladaptive digital learning states (Wang & Liu, 2022). Collectively, such indigenous theoretical refinement can substantially improve the explanatory and predictive validity of flow theory when applied to local educational settings.

6.2 Methodological Renewal

Future pedagogical flow research requires comprehensive methodological diversification to address the static, single-method limitations that have constrained empirical rigor in prior studies (Van der Linden et al., 2021). Specifically, scholars should expand longitudinal tracking protocols and adopt the Experience Sampling Method (ESM) to capture real-time, day-to-day fluctuations in classroom flow, overcoming the retrospective bias and temporal limitations inherent in conventional cross-sectional surveys (Fullagar & Kelloway, 2009). To further enhance measurement objectivity and mitigate self-report mono-source bias, multi-modal educational neuroscience and learning analytics techniques—including eye-tracking monitoring, physiological sensing, and classroom behavioural big data mining—should be systematically integrated to triangulate subjective flow perceptions with objective behavioural and neural evidence (Chen et al., 2023; Wang & Liu, 2022). Methodologically, future inquiries should also move beyond oversimplified linear structural equation modelling (SEM) by adopting advanced analytical paradigms, including fuzzy-set Qualitative Comparative Analysis (fsQCA), systematic meta-analysis, and multi-group experimental designs; such configurational and comparative methods are better suited to unpacking the complex, non-linear, and condition-dependent causal pathways of flow formation, thereby enabling a more nuanced understanding of how multiple factors jointly shape optimal and maladaptive learning immersion (Hasan & Bao, 2022; Hair et al., 2019).

6.3 Expansion of Research Content: Addressing Underexplored Scholarly Gaps

To enrich the dimensional breadth of pedagogical flow research and fill prominent empirical voids identified in existing literature, future scholarship should extend its research scope toward three underexamined yet theoretically and practically significant domains. First, emerging digital learning ecologies demand targeted investigation into the formation mechanisms of pseudo-flow, a maladaptive immersive state prevalent in AI-adaptive learning systems, metaverse-based virtual classrooms, and fragmented short-video microlearning scenarios, where algorithm-driven content recommendation and low-cognitive-load interaction often foster superficial engagement rather than deep knowledge construction (Chen et al., 2023; Onesí-Ozigagun et al., 2024). Second, research should shift beyond dominant samples of mainstream urban student groups to explore differentiated flow cultivation pathways for marginalised and vulnerable learner cohorts, including rural students with insufficient educational resources, special education learners with diverse learning needs, and low-digital-literacy populations who face unique environmental and individual barriers to achieving stable academic flow (Li et al., 2023). Third, given the longstanding overemphasis on flow's positive educational outcomes, future inquiries must systematically examine the adverse side effects of excessive learning immersion, focusing on identifying the generative preconditions of cognitive

fatigue, learning over-immersion and tech-induced academic addiction, while developing targeted instructional and technological intervention strategies to mitigate such maladaptive outcomes and achieve balanced, sustainable immersive learning (Wang & Liu, 2022).

6.4 Deepened Practical Translation

To bridge the persistent theory–practice disconnection in existing flow research and enhance the practical convertibility of pedagogical flow principles, future applied studies should prioritise the systematic development of standardised, scalable, and context-adaptive intervention systems for classroom and digital learning environments (Jiang et al., 2021). First, discipline-specific and stage-stratified modular instructional handbooks should be formulated to provide grade-adaptive, subject-targeted flow design procedures, resolving the pervasive issue of homogenised and non-operational instructional strategies that dominate current pedagogical guidelines (Martin et al., 2023). Second, unified industry-level interactive design specifications need to be established for smart learning platforms, offering empirically validated criteria for interface optimisation, adaptive difficulty adjustment, real-time feedback mechanism configuration and immersive rhythm regulation, thereby reducing arbitrary developmental heterogeneity in existing educational technology products (Chen et al., 2023; Wang & Liu, 2022). Third, systematic teacher training curricula tailored for primary, secondary, and tertiary educational contexts should be developed and empirically validated, equipping educators with professional competencies to recognise real-time flow fluctuations, calibrate task challenge, and prevent maladaptive over-immersion during instruction (Bressler & Bodzin, 2013). Collectively, this multi-layered practical system can facilitate the large-scale, sustainable implementation of flow-oriented pedagogy and realise the effective translational application of theoretical research findings.

7.CONCLUSION

As a bridge connecting positive psychology and frontline classroom practice, flow theory delivers irreplaceable explanatory power and practical value amid educational digital transformation and deep learning reforms. While abundant empirical findings have accumulated over the past two decades, domestic research remains constrained by weak indigenous theoretical construction, mono-method static quantitative dominance, limited inquiry into negative flow themes and insufficient translation of research into pedagogical practice. Future scholarship must root itself within China's indigenous educational contexts, advance indigenous theoretical innovation and pluralistic renewal of research paradigms, balancing foundational theoretical construction with frontline pedagogical implementation. Researchers should fully exploit the capacity of flow theory to foster intrinsic learning motivation, construct immersive high-efficiency classrooms and resolve the dilemma of superficial learning, providing psychological support for the development of a high-quality education system.

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