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Molecular & Cellular Biomechanics 2025, 22(4), 1706.
https://doi.org/10.62617/mcb1706

Article

The integration of Chinese language education and Chinese language and literature education in complex environments: A new perspective based on biomechanics and molecular mechanisms

Jianqiang Wang*, Jingjing Guo

Henan Economy and Trade Vocational College, Zhengzhou 450018, China
*** Corresponding author:** Jianqiang Wang, wangjq@henetc.edu.cn

CITATION

Wang J, Guo J. The integration of Chinese language education and Chinese language and literature education in complex environments: A new perspective based on biomechanics and molecular mechanisms. Molecular & Cellular Biomechanics. 2025; 22(4): 1706. https://doi.org/10.62617/mcb1706

ARTICLE INFO

Received: 27 February 2025
Accepted: 5 March 2025
Available online: 14 March 2025

Abstract: This research explores the scientific foundations, practical pathways, and effects of integrating Chinese language education with Chinese language and literature education in complex environments, using the systems thinking of biomechanics and molecular mechanisms as a perspective. The study employed a randomized controlled experimental design, selecting 184 Chinese language and literature majors from six universities across Eastern China, Northern China, and Southwest regions. Participants were divided into an experimental group (receiving an integrated education model) and a control group (receiving a traditional separated teaching model). Through a 12-week teaching intervention, using diversified data collection tools and mixed research methods, the study systematically evaluated the effectiveness of integrated education. The research found that: (1) Integrated education significantly improved learners' originality (+27.75%), understanding of complexity (+25.27%), functional application (+23.16%), and aesthetic perception (+28.92%); (2) it achieved a win-win situation in learning efficiency and quality, forming an "efficiency-quality virtuous cycle"; (3) learning engagement, as a key mediating variable, explained 62.8% of the positive impact of integrated education on learning outcomes; (4) interdisciplinary theme integration (r = 0.72), diverse forms of expression (r = 0.68), and problem-oriented task design (r = 0.64) were key teaching elements affecting the effectiveness of integrated education; (5) integrated education positively impacted learners with different characteristics, but integrative learners (d = 0.59) and intrinsically motivated learners (d = 0.65) benefited more; (6) teacher professional competence (relative importance = 0.86), curriculum integration (relative importance = 0.76), and learner autonomy (relative importance = 0.78) were key conditions for successful integrated education, while time pressure (impact intensity = 0.74) and evaluation system incompatibility (impact intensity = 0.68) were major limiting factors. Based on these findings, the study constructed a theoretical framework for the integration of language and literature education and proposed practical implications including reconstructing the curriculum system, innovating teaching methods, transforming evaluation mechanisms, and strengthening teacher development. These conclusions not only confirm the scientific rationality and practical feasibility of integrating Chinese language education with Chinese language and literature education, but also provide a theoretical basis and practical pathways for constructing innovative education models adapted to complex environments, which has important implications for promoting Chinese language education reform.

Keywords: Chinese language education; Chinese language and literature education; educational integration; systems thinking; creative thinking; complexity understanding

1. Introduction

In the rapidly changing contemporary educational environment, the integrated development of Chinese language education and Chinese language and literature

education faces unprecedented opportunities and challenges. With the acceleration of globalization and the rapid development of information technology, traditional models of Chinese language education and Chinese language and literature education are struggling to meet the demands of the new era, urgently requiring the exploration of innovative integration pathways. As Zuo emphasized, the construction of university Chinese language and literature education environments is a key factor in enhancing teaching effectiveness; good campus environments not only provide physical spaces for learners but also create a cultural atmosphere immersed in language and literature [1]. This consideration of environmental construction and educational integration is essentially a response to the complexity of teaching systems. Educational transformation in the new media environment further highlights this complexity. Wu pointed out that the popularization of digital technology has not only changed the way information is acquired but has also profoundly influenced the processes of language acquisition and literary appreciation, requiring educators to innovate teaching methods, integrate diverse resources, and achieve deep integration of language and literature education [2]. Particularly against the backdrop of the national strategy for rural revitalization, Zhai's research revealed regional imbalances and resource inequalities in current Chinese language and literature education, practical challenges that prompt us to consider the social value and practical pathways of educational integration from a more macro perspective [3].

The complexity of education is not only manifested in the domestic environment but is especially evident in international contexts. Barnawi's study on Chinese education policies in the Arabian Gulf region shows that language education has become an important vehicle for international political, economic, and cultural exchange, with new educational subjects and discourse systems forming a diverse language market [4]. This language education policy transformation in the globalization trend has an intrinsic connection with the integration issues of language and literature education we are discussing—both need to find integration points in complex systems. Alhinai analyzed the case of Chinese foreign language education in Oman from a neoliberal ideological perspective, revealing the implicit economic logic and value orientation in language education, reminding us that in advancing educational integration, we cannot ignore considerations at the level of ideology and educational philosophy [5]. Current educational integration concerns not only the integration of teaching methods and content but also the unification of educational concepts and value orientations. From a global perspective, Lou and Chen emphasized research on pathways to enhance the global competence of international Chinese education master's students, and this emphasis on cross-cultural communication abilities and international perspectives precisely reflects the trend that Chinese language education needs multi-dimensional development in complex environments [6].

This research approaches the integration of Chinese language education and Chinese language and literature education from the novel perspective of biomechanics and molecular mechanisms, exploring the scientific foundations and practical pathways for this educational fusion. Although biomechanical research primarily focuses on human movement and structure, its systems thinking and data analysis

methods provide insightful implications for understanding education as a complex system. Specifically, the force equilibrium principle in biomechanics can be directly analogized to the balanced development of skills in language and literature education; just as the muscular system requires antagonistic muscle groups working collaboratively to maintain stability, language skills (such as grammar and rhetoric) and literary perception abilities (such as aesthetics and criticism) also need coordinated development to form comprehensive language literacy. The self-organizing nature of molecular mechanisms maps onto the knowledge network formation process in educational integration—similar to how protein molecules achieve functions through specific spatial conformations, language and literary knowledge points form structured cognitive networks through organic connections rather than simple linear superposition. Furthermore, the stress-strain relationship in mechanics precisely corresponds to the relationship between teaching challenges and learners' adaptive growth, where moderate cognitive challenges (stress) can promote the elastic development of learners' abilities (strain), but excessive challenges may lead to learning frustration (similar to materials' yield point). By introducing systematic analysis methods from biomechanics, we can more precisely quantify key variables in the educational integration process, such as teaching content complexity, learner engagement and creative performance, and time efficiency of integrated teaching; for example, we can adapt molecular diffusion dynamics models to analyze knowledge propagation patterns within learning groups and apply stress distribution mapping techniques to visualize learning difficulty distributions—this quantitative analysis approach provides new possibilities for traditionally subjective educational evaluation and contributes to constructing a more scientific assessment system for educational integration models.

To clarify the theoretical framework, it is necessary to explain how specific principles of biomechanics and molecular mechanisms precisely map onto the integration of Chinese language and literature education. In biomechanics, draw upon three core concepts: (1) The "force analysis" principle from structural mechanics is used to deconstruct teaching content structure, identifying supportive relationships between language skills (such as grammar and rhetoric) and literary appreciation abilities (such as thematic analysis and style recognition), forming a "knowledge mechanical structure diagram" that guides the proportional and sequential arrangement of elements in instructional design; (2) the "pressure gradient" concept from fluid mechanics is employed to optimize the difficulty distribution of learning tasks, designing difficulty sequences that conform to the "zone of proximal development", creating a positive flow between language learning and literary appreciation; (3) the "fatigue-recovery" mechanism from biomaterial mechanics is applied to learning rhythm design, alternating analytical language tasks with immersive literary experiences to optimize cognitive load. Regarding molecular mechanisms, three key principles are applied: (1) Molecular recognition and signal transduction mechanisms map onto the process of constructing associations between linguistic forms and literary connotations, designing 'form-meaning connection tasks' that strengthen the relationship between language structures and aesthetic experiences; (2) the molecular self-assembly principle guides the formation of organic associations between knowledge points, creating problem situations that promote learners'

autonomous construction of knowledge networks; (3) the principle of interaction balance between biomolecules is applied to content selection in integrated curricula, ensuring a balanced ratio between basic language knowledge (analogous to skeletal molecules) and higher-order literary experiences (analogous to functional molecules). After these specific principles are transformed into educational strategies, they form this research's "bio-educational mechanics integration model", providing a practical scientific framework for traditionally vague integrated education.

It needs to be emphasized that this research does not simply mechanically apply biomechanical concepts to the educational field but borrows its systems thinking and analytical frameworks to explore the internal mechanisms of language and literature education integration. Educational integration is not a simple addition of content or combination of methods but a complex systemic project involving multiple dimensions such as cognition, emotion, and socio-culture. Just as biological systems achieve functional integration through multi-level molecular interactions, effective educational integration also needs to coordinate the relationship between language ability cultivation and literary literacy enhancement at multiple levels. In practice, this means designing teaching activities that simultaneously activate language ability and literary appreciation ability, creating learning environments that promote mutual enhancement of both abilities, and developing evaluation tools that comprehensively assess multi-dimensional development.

Through rigorous experimental design and statistical analysis, this research explores the impact of different integration models on learners' core competencies such as creativity, comprehension, and aesthetic ability. Participants were divided into a control group and an experimental group, with the former adopting traditional separated teaching methods and the latter receiving science data-based integrated teaching models. By comparing the differences between the two groups in terms of originality, understanding of complexity, functional application, and aesthetic perception, this study quantifies the effects of integrated education and identifies key factors influencing these effects. This research method based on experimental data not only provides empirical support for theoretical construction but also offers concrete and feasible guidance for educational practice.

2. Literature review

In contemporary educational research, the integration of Chinese language education and Chinese language and literature education has become an important topic of scholarly attention. With the advent of the digital era and the increasing complexity of educational environments, traditional teaching models and methods face severe challenges, making the necessity and urgency of integrated education increasingly prominent. This chapter will systematically review relevant research findings both domestically and internationally, providing theoretical support and methodological references for this study.

2.1. Transformation of language and literature education in the new media environment

The rapid development of new media technology has profoundly changed the

ecological environment of Chinese language education and Chinese language and literature education. Zhou explored optimization strategies for Chinese language and literature teaching in open education under the network language environment, pointing out that the popularization of network language presents new challenges to traditional language teaching, requiring educators to incorporate network language phenomena into their teaching perspective and guide students to discern and understand the contextual applicability of network expressions [7]. In response to this, Zhou, through an analysis of the current state of Chinese language and literature major teaching in the new media environment, revealed problems such as disconnection between teaching content and social demands, misalignment between teaching methods and student expectations, and proposed improvement strategies including modernization of teaching content and diversification of teaching methods [8].

Wang, approaching from the perspective of literature education, commented on new pathways for university literature education against the backdrop of new media, emphasizing that digital technology has not only changed the way literary works are disseminated but has also influenced students' reading habits and aesthetic orientations, requiring literature education to break free from the constraints of traditional teaching models and explore teaching methods suitable for the new media context [9]. Ge further explored the classic reading and experiential modes of Chinese language and literature in the network environment, noting that while digital reading is convenient and efficient, it also brings problems such as fragmented reading and reduced depth of thinking, proposing a mixed reading strategy that integrates online and offline approaches [10].

Sun, in "Optimization Strategies for Chinese Language and Literature Teaching in the New Media Environment", proposed that teachers should fully utilize the advantages of new media technology to construct interactive teaching scenarios, promote teacher-student exchange and student-student interaction, and enhance the learning experience [11]. Wang, thinking from the perspective of the digital media environment on the development of Chinese language and literature, believed that digital technology provides new platforms for literary creation and dissemination and brings rich teaching resources for language education, but also brings challenges such as information overload and shallow reading, requiring the cultivation of students' information filtering abilities and critical thinking in education [12]. Bai analyzed the influence of the network environment on the development of Chinese language and literature, pointing out that the rise and development of internet literature has become an important component of contemporary literature, requiring language education to pay attention to internet literature phenomena and incorporate them into teaching content [13].

Jiang [14] and Wang [15] both explored new pathways for the development of Chinese language and literature in the new media environment. They consistently believed that new media is both a challenge and an opportunity, with the key being how to use the advantages of new media to promote the integration of traditional and modern, achieving innovation in teaching methods. Zhang focused on the standardized and diversified development of Chinese language and literature in the new media environment, proposing that on the basis of respecting language norms, diverse cultural expressions should be embraced to promote the open development of language

and literature education [16].

2.2. Teaching model innovation in open education environments

Open education provides new possibilities for the integration of language and literature education. Guo studied effective teaching strategies for adults in the network environment, using open education Chinese language and literature teaching as an example, exploring how to design flexible and diverse teaching activities that align with the characteristics of adult learners to enhance learning effectiveness [17]. The study emphasized that adult education needs to focus on the combination of theory and practice, guiding students to integrate language learning with career development and life needs, enhancing learning motivation and practicality.

Yan conducted an in-depth study on teaching model innovation for Chinese language and literature majors in open education environments, pointing out that traditional teaching models place too much emphasis on knowledge transmission while neglecting ability cultivation and quality enhancement. She recommended adopting innovative models such as project-based learning and cooperative learning to promote students' active participation and deep thinking [18]. Ni, based on the open education environment, analyzed innovations in Chinese language and literature teaching, proposing systematic reform ideas for teaching content, teaching methods, and teaching evaluation, emphasizing the importance of combining traditional cultural elements with modern educational technology [19].

Li explored the application of inquiry-based teaching methods in middle school Chinese language and literature education, analyzing challenges in the teaching process and their solutions [20]. The research showed that inquiry-based teaching can effectively stimulate students' learning interest and initiative, but faces challenges such as insufficient teacher guidance ability and uneven student participation during implementation. This study provided concrete and feasible teaching strategies for the integration of language and literature education at the secondary school level.

Ji focused on the cultivation of language skills and cultural literacy in Chinese education, emphasizing that language learning should not be limited to grammar rules and vocabulary accumulation but should also include cultural understanding and cross-cultural communication abilities, providing a cultural perspective for the integration of language education and literature education [21]. The study proposed that integrated education should focus on the unity of language form and cultural connotation, understanding the cultural implications behind language through literary works, while also deepening the understanding and appreciation of literary works through language learning.

2.3. Educational practices in diverse cultural and linguistic environments

In the context of globalization, multicultural and multilingual environments have posed new requirements for language education. Zhang researched the influence of family language environments on bilingual education for preschool children, finding that family language usage habits and parental language attitudes have significant impacts on children's language acquisition. Although this research focused on the preschool stage, it provides insights into understanding how early language

environments affect subsequent language learning [22].

Pei, based on third language acquisition theory, studied the current state of English education in minority-concentrated areas of Sichuan under multilingual environments, revealing the complexity and challenges of language learning in multilingual contexts [23]. Although this research focused on English education, its analysis of language teaching strategies in multilingual environments provides reference value for implementing Chinese language and literature education in multicultural backgrounds.

From an international perspective, Song examined the fifty-year history of community-based and formal Chinese education development in California, USA, analyzing the impact of language policy changes on Chinese education and the important role of community strength in language heritage preservation [24]. This research reminds us that language education is not only the responsibility of school education but also requires the joint participation of families and communities to form an educational synergy.

Chen conducted comparative research on the relationship between Chinese education in Malaysia and Indonesia and their national conditions, revealing differences and commonalities in Chinese education under different national backgrounds [25]. The research emphasizes that language education must adapt to local sociocultural environments and policy backgrounds, a viewpoint that is equally inspirational for our thinking about language education in different regions within China.

Han explored the application of translanguaging as a pedagogy in Chinese education, analyzing how teachers and students utilize bilingual abilities to promote language learning [26]. This research shows that allowing students to flexibly use their native language and target language during the learning process can reduce learning anxiety and improve comprehension efficiency, providing important implications for our thinking about language education for students from multilingual backgrounds.

Yang researched teaching strategies for Chinese education in multicultural backgrounds, pointing out that in the context of globalization, Chinese education needs to balance language skill cultivation with cultural understanding, adopting flexible and diverse teaching methods to adapt to the needs of students from different cultural backgrounds [27]. This research emphasizes the importance of cultural sensitivity in language education, providing a cultural perspective for the integration of language and literature education.

Jia et al. conducted comparative research on narrative strategies in international Chinese education, analyzing the narrative characteristics and effects of different cultural dissemination institutions based on the overseas dissemination practices of Confucius Institutes and Goethe Institutes [28]. The research shows that effective language education needs to combine the cultural background and cognitive habits of the target audience, which provides inspiration for our thinking about the cultural adaptability of language education.

2.4. Research gaps and innovation points of this study

Through a systematic review of existing literature, we can identify that although

rich research findings have accumulated regarding language education and literature education in new media environments, and language education in open education models and multicultural backgrounds has received widespread attention, there remain several research gaps that need to be addressed.

(1) Existing research mostly explores educational reform from specific aspects such as teaching content, teaching methods, and teaching evaluation, lacking systematic theoretical construction for the integration of Chinese language education and literature education, especially lacking analytical frameworks based on scientific perspectives. This study attempts to introduce the systems thinking of biomechanics and molecular mechanisms to provide a new theoretical perspective for educational integration, which is expected to fill this gap.

(2) Most studies employ qualitative analysis methods, lacking support from rigorous empirical research, with educational effect assessments largely relying on subjective experience. This study will design controlled experiments using quantitative analysis methods to objectively evaluate the educational effects of different integration models, enhancing the scientific nature and reliability of the research [29].

(3) Existing research rarely focuses on the impact of individual learner differences on the effectiveness of educational integration, neglecting the complex dynamic changes in the learning process. This study will attend to individual factors such as learners' cognitive characteristics and learning styles, analyzing their interactive effects with educational integration models to provide a scientific basis for personalized education.

(4) There is insufficient dialogue between domestic and international research, lacking comparative analysis from cross-cultural perspectives. This study will draw on research findings on language education from an international perspective, combining them with the actual situation of Chinese language education in China to explore an educational integration model with Chinese characteristics.

In summary, based on existing research findings, this study attempts to construct a scientific framework for the integration of Chinese language education and Chinese language and literature education by introducing new theoretical perspectives and research methods, exploring the internal mechanisms and practical pathways of educational integration in complex environments, with the aim of providing theoretical support and practical guidance for educational reform. Through interdisciplinary research, we expect to reveal the deep connections between language learning and literary appreciation, providing more scientific and effective educational programs for cultivating students' language abilities, literary literacy, and innovative thinking.

3. Research methods

3.1. Research design

This study employs an experimental design method aimed at exploring the impact of integrated models of Chinese language education and Chinese language and literature education on learning outcomes. Based on the literature review and theoretical analysis, this study proposes three core hypotheses: Hypothesis 1 suggests that the integrated education model can significantly improve learners' originality, a

hypothesis built on the theoretical foundation that educational integration can promote cross-domain thinking and the development of innovation abilities, by integrating language skills training with literary appreciation activities to stimulate learners' creative expression and unique insights; Hypothesis 2 proposes that the integrated method can enhance understanding of content complexity, expecting that through the combination of language analysis tools and literary interpretation methods, learners will be helped to understand the internal structure and deeper meaning of texts from multiple dimensions, cultivating their systems thinking ability and knowledge integration ability; Hypothesis 3 advocates that integrated education enhances learning functionality and aesthetic perception, with the core view being the mutually promoting relationship between language skills and literary literacy, where integrated education not only improves learners' practical language abilities but also cultivates their literary appreciation abilities and aesthetic judgment.

The framework of this study consists of three main parts: (1) Formation of a control group (traditional separated teaching model) and an experimental group (integrated education model) through random grouping, ensuring no significant differences between the two groups in terms of learning foundations, gender ratio, age distribution, etc.; (2) implementation of a 12-week teaching intervention, with the experimental group receiving a comprehensive curriculum designed based on integration concepts, and the control group separately receiving traditional language courses and literature courses; (3) collection and analysis of quantitative and qualitative data through a pre-test-post-test design to evaluate the actual effects of integrated education [30]. In terms of variable definition and operationalization, this study identifies the teaching model (integrated or separated) as the independent variable, with dependent variables including originality, understanding of complexity, functional application, and aesthetic perception across four dimensions.

Originality is measured through creative writing task scoring, evaluated by three experts on a 1–10 scale based on uniqueness of thought, novelty of expression, and innovation in problem-solving; understanding of complexity is assessed through text analysis tests and knowledge structure maps, measuring the depth and breadth of learners' understanding of complex texts, as well as the richness of connections between knowledge points; functional application is evaluated through situational application tasks and practical writing assessments, examining the effectiveness of learners in using language abilities to solve problems in real scenarios; aesthetic perception is assessed through literary appreciation tests and aesthetic judgment tasks, measuring learners' ability to perceive the artistic value of literary works and the formation of aesthetic preferences. At the same time, this study controls variables that might affect experimental results, including learners' prior knowledge level, teachers' teaching experience, time invested in learning, etc., ensuring the internal and external validity of the research through random grouping, teaching plan standardization, and process monitoring measures.

3.2. Participant selection

This study employed a stratified random sampling method, selecting a total of 184 undergraduate students majoring in Chinese Language and Literature from six

universities in Eastern China, Northern China, and Southwestern regions. The selection of these three regions aimed to balance regional representation and educational resource differences to enhance the applicability of research findings. The participants' grade distribution was 92 sophomores (50%) and 92 juniors (50%), with a gender composition of 128 females (69.6%) and 56 males (30.4%), an age range of 19–23 years, and an average age of 20.7 years. The selection of sophomore and junior students mainly considered that they had completed foundational coursework, possessed a certain professional knowledge base, and had not yet entered the graduation internship stage, enabling them to participate fully in the semester-long experimental teaching. All participants voluntarily participated in this study and signed informed consent forms, and the research protocol was also reviewed by the university ethics committee. To ensure balanced experimental conditions, participants were randomly assigned to the experimental group (92 people) and the control group (92 people), with no significant differences ($p > 0.05$) between the two groups in key variables such as gender, age, academic performance (previous academic year's Grade Point Average (GPA), and professional interest level (measured by pre-experimental questionnaire). The distribution of participants' family backgrounds was urban (58.7%), county-level cities (26.1%), and rural (15.2%); family income levels: High (22.3%), middle (61.4%), and low (16.3%); parents' educational attainment: University and above (46.2%), high school (38.5%), and junior high school and below (15.3%). Regarding prior learning experiences, 67.4% had long-term reading habits, 35.8% regularly participated in creative writing activities, and 28.9% had participated in interdisciplinary learning projects.

To ensure the representativeness of the research sample and the reliability of the data, this study established strict participant screening criteria. (1) All participants must be Chinese students with Chinese as their mother tongue, excluding learning effect biases that might result from language background differences; (2) participants' high school Chinese exam scores before university admission should not be lower than 90% of the key admission line in their province, ensuring a basic level of Chinese literacy; (3) participants should have no record of long-term absences (attendance rate not lower than 85% in the previous academic year) to ensure continuity during the experimental process; finally, through pre-test assessment of participants' cognitive styles, learning motivation, and technology acceptance, the balance of these potential influencing factors between the experimental group and control group was ensured. Notably, this study paid special attention to participants' cognitive diversity, ensuring a balanced distribution of learners with different cognitive styles (such as field-independent versus field-dependent, analytical versus integrative) in both groups on the basis of random grouping, providing a foundation for subsequent analysis of the performance of different types of learners in integrated education [31]. During the screening process, there were originally 204 registrants, with 184 ultimately determined to participate in the research after standard screening, giving a screening elimination rate of 9.8%, with the main reasons including personal time conflicts, incomplete background information, and lack of sustained participation willingness.

To further enhance the ecological validity of the research, this study also included 18 teachers as teaching implementers and observers. These teachers included 6 language education experts, 6 literature education experts, and 6 interdisciplinary

education researchers, with an average teaching experience of 12.3 years, possessing rich teaching experience and disciplinary backgrounds. All teachers participated in a two-week specialized training, with content including an introduction to research purposes, integrated education concepts and methods, teaching plan standardization, and assessment tool usage. The training ensured teachers' consistent understanding of research objectives and standardization of teaching implementation, reducing experimental biases that might arise from individual teacher differences. Meanwhile, teachers were randomly assigned to the experimental group and control group, with each teacher simultaneously participating in teaching activities for both groups, balancing possible teacher effects through a crossover design. Additionally, the research invited 6 educational psychology and assessment experts to form an assessment team responsible for objectively evaluating participants' learning outcomes. The assessment experts operated independently from the teaching teachers and were unaware of which group the participants belonged to, ensuring the fairness and reliability of assessment results.

3.3. Data collection tools and techniques

This study employs diversified data collection tools and techniques to ensure comprehensive and precise experimental data. First, for the assessment of learner originality, a "Creative Expression Assessment System" (CEAS, Creative Expression Assessment System) was designed, which includes three core tools: (1) A creative writing task set covering various genres such as narrative, argumentative essays, and poetry creation, to be completed by participants before and after the experiment; (2) an originality scoring scale adapted from the Torrance Tests of Creative Thinking framework, scoring on a 10-point scale across four dimensions: Fluency, flexibility, originality, and elaboration; (3) a textual linguistic feature analysis tool using natural language processing technology to quantitatively analyze the Measure of Textual Lexical Diversity (MTLD), syntactic complexity, and frequency of rhetorical device usage in participants' works [32]. All creative works were independently scored by three scoring experts, with an inter-rater reliability of 0.87 (Cronbach's α coefficient), ensuring consistency and reliability of scoring.

The choice of CEAS instead of traditional standardized creativity tests (such as the Torrance Tests of Creative Thinking) was based on three considerations: (1) CEAS was specifically designed for integrated language and literature environments, including domain-specific assessment dimensions, while most standardized tools are overly generic; (2) CEAS integrates quantitative and qualitative assessment methods, capable of more comprehensively capturing the multidimensional characteristics of linguistic creativity; (3) this tool underwent two rounds of expert Delphi method evaluation and small-scale preliminary testing (n = 42) verification, achieving a Content Validity Index (CVI) of 0.87 and test-retest reliability of 0.85, significantly outperforming existing general tools in the language domain (with an average reliability of 0.76). During tool development, factor analysis identified four key dimensions that best differentiate between the effects of integrated education and traditional education, and specific measurement tasks were designed for each dimension, ensuring the tool's sensitivity and specificity to the study's core variables.

For the measurement of complexity understanding, a "Text Complexity Understanding Assessment System" (TCUS) was developed, integrating methods from cognitive science and literary analysis. Specific tools include: (1) A multi-level text comprehension test, including literal understanding, inferential understanding, evaluative understanding, and creative understanding levels, with test items reviewed by experts and analyzed for pre-test reliability and validity (KR-20 coefficient of 0.85); (2) a concept mapping task requiring participants to draw connection networks between key concepts in texts, quantifying the structural understanding through evaluation of the number of concept nodes, connection complexity, and hierarchical depth; (3) a cross-text analysis task measuring learners' ability to integrate information from multiple texts and identify intrinsic connections; (4) a thinking process tracking system using the think-aloud protocol to record participants' cognitive processes when reading complex texts, combined with eye-tracking technology (Tobii Pro Spectrum eye tracker) to collect objective indicators such as reading dwell time and regression frequency, analyzing the relationship between deep processing and understanding. All measurement tools underwent small-scale pre-testing (n = 38) before the formal experiment, and the test content and process were optimized accordingly to ensure the effectiveness and operability of measurement [33].

For the assessment of functional application ability, the study designed a "Language Application Situational Test" (LAST), comprehensively evaluating participants' language application abilities through simulated real language use scenarios. This assessment includes: (1) Practical writing tasks including official document writing, explanatory writing, and applied writing, with evaluation criteria including goal achievement, genre conformity, language accuracy, and expression efficiency; (2) multimodal communication tasks combining oral expression, written communication, and digital media usage, evaluating participants' language adaptation abilities in different contexts; (3) problem-solving situation simulations setting complex problem scenarios requiring language skills to solve, evaluating participants' strategy selection and execution effectiveness; (4) language analysis and application reports requiring participants to analyze specific language phenomena and propose application suggestions, measuring their ability to transform language knowledge into practice. All functional tasks are accompanied by detailed scoring criteria and scoring examples, with cross-scoring by two groups of raters achieving an inter-group consistency coefficient of 0.84.

For the measurement of aesthetic perception ability, a "Literary Aesthetic Perception Evaluation Toolkit" (LAPE) was developed, integrating traditional literary criticism methods and modern aesthetic measurement techniques. Specifically, it includes: (1) A literary work appreciation questionnaire covering classical and modern literary works, testing participants' ability to perceive textual artistic features and make aesthetic judgments, using a 7-point Likert scale with an internal consistency coefficient of 0.89; (2) aesthetic preference and judgment tests evaluating participants' aesthetic tendencies and discrimination abilities through comparison of literary excerpts of different artistic styles; (3) an emotional response measurement system combining physiological indicator monitoring (such as electrodermal response, heart rate variability) and self-report scales to record the intensity and types of emotional experiences participants have when reading literary works; (4) an aesthetic evaluation

scale assessing participants' ability to aesthetically evaluate literary works from four dimensions: Formal beauty, content beauty, artistic conception beauty, and innovative beauty. To enhance the ecological validity of measurement, we specially designed an "Immersive Literary Experience Environment", reproducing the historical background and artistic atmosphere of literary works through multimedia technology to collect aesthetic response data under conditions approaching natural reading states.

3.4. Experimental procedure

This research's experimental procedure is divided into three key stages: The preparation stage, the implementation stage, and the evaluation stage, with the entire experiment lasting 16 weeks. In the preparation stage (Weeks 1–2), pre-test assessments were first conducted for all participants to collect baseline data, including originality ability tests, complexity understanding level evaluations, functional application ability measurements, and aesthetic perception ability tests, ensuring no significant differences in starting levels between the experimental and control groups. Meanwhile, the research team conducted a 10-day specialized training for 18 teachers, with content covering integrated education concepts, teaching plan implementation details, assessment tool usage standards, and data collection processes [34]. The training combined theoretical explanation with simulated teaching, ensuring all teachers reached a consistent understanding of experimental objectives and methods through case analysis, teaching demonstrations, and feedback discussions.

The implementation stage (Weeks 3–14) was the core component of the experiment, with 12 weeks of teaching intervention simultaneously conducted across six universities. The experimental group received a comprehensive curriculum designed based on integration concepts, with 6 class hours per week. The course content integrated language learning and literary appreciation, with teaching activities designed following the path of "language expression, literary experience, integration, and innovation", emphasizing the mutual promotion of language ability and literary literacy. Specific teaching strategies included theme-based integration units (such as "The Power of Language and the Charm of Literature"), multi-dimensional text interpretation (from linguistic structure to cultural connotation), creative writing workshops (integrating language skills with literary expression), and cross-media expression projects (transforming text into other art forms). The control group received traditional separated teaching, also with 6 class hours per week, but divided into language courses (3 h) and literature courses (3 h), with the two types of courses taught by different teachers, and content and methods following traditional teaching models. During implementation, the research team conducted teaching observations every two weeks, recording teaching realities and collecting teacher teaching journals and student learning journals to monitor the standardization and coherence of the experimental process. Meanwhile, mid-term evaluations were conducted in Week 7, mainly through questionnaires and group interviews, to understand participants' learning experiences and feedback, with adjustments made to the latter half of teaching based on this, but without changing the basic experimental design.

The evaluation stage (Weeks 15–16) primarily completed post-test data collection and preliminary analysis. All participants completed assessment tasks that

were parallel to but not identical with the pre-test content, including four aspects: Creative writing, text comprehension, functional application, and aesthetic judgment. Assessment tools remained consistent with the pre-test, but content was updated to avoid practice effects. At the same time, participant evaluations of course experiences were collected through questionnaires, covering dimensions such as learning satisfaction, content appropriateness, difficulty perception, and future expectations. Additionally, the research team conducted in-depth interviews with 30 randomly selected participants from each group to explore their subjective feelings and learning gains from integrated or separated teaching models. All tests and interviews were conducted in standardized environments, with assessors unaware of which group participants belonged to, to reduce subjective bias. After data collection was completed, the research team immediately conducted data organization and preprocessing, including scale scoring, interview transcription, and coding, in preparation for subsequent statistical analysis.

3.5. Data analysis methods

This study adopts a mixed research methodology, comprehensively applying quantitative and qualitative analysis techniques to process experimental data. For descriptive statistical analysis, SPSS 26.0 software was used to calculate the mean, standard deviation, skewness, and kurtosis of each variable to examine data distribution characteristics. Frequency analysis was conducted for demographic variables (such as gender, age, school distribution) to ensure matching of basic characteristics between the experimental and control groups. Meanwhile, data distribution was visually presented through visualization methods such as histograms, box plots, and Q-Q plots, and the normality of major variables was assessed using Kolmogorov-Smirnov tests and Shapiro-Wilk tests, providing a basis for the application of subsequent parametric tests. To enhance the rigor of the analysis, we also calculated reliability indicators (Cronbach's α coefficients) and item discrimination for each scale, ensuring the quality of measurement tools [35]. Additionally, correlation analysis was used to preliminarily explore association patterns among variables, providing direction for subsequent in-depth analysis.

For the verification of research hypotheses, this study primarily employed variance analysis and multiple regression analysis. First, paired-sample t-tests were used to analyze changes within each group before and after the experiment, evaluating the within-group significance of intervention effects. Second, mixed-design analysis of variance (2 × 2 ANOVA, with teaching model as the between-subjects factor and testing time as the within-subjects factor) was adopted to examine between-group differences in intervention effects, with special attention to interaction effects, verifying whether the impact of integrated education on learning outcomes was significantly superior to traditional separated education. For data not meeting parametric test conditions, non-parametric test methods such as Mann-Whitney U tests and Wilcoxon signed-rank tests were employed for analysis. To explore relationship patterns among multiple dependent variables, the study also utilized multivariate analysis of variance (MANOVA), simultaneously examining the comprehensive impact of integrated education on the four dimensions of originality, complexity

understanding, functional application, and aesthetic perception. After controlling for potential confounding variables (such as prior academic performance and learning motivation), analysis of covariance (ANCOVA) was further used to verify the purity of intervention effects.

To gain a deeper understanding of the mechanisms of integrated education, this study employed structural equation modeling (SEM) to analyze causal relationships among variables. AMOS 24.0 software was used to construct measurement models and structural models, evaluating the direct and indirect effects of integrated education on various learning outcomes. Model fit was evaluated through multiple indicators, including χ^2/df (< 3 is preferable), CFI (>0.95 is preferable), TLI (> 0.95 is preferable), RMSEA (< 0.06 is preferable), and SRMR (< 0.08 is preferable). Through mediation effect analysis, the study explored whether integrated education affects final learning outcomes through intermediate variables such as increased learning engagement and deep learning strategies. At the same time, multi-group analysis was used to test the stability of the model across different subgroups such as gender and cognitive styles, evaluating the universality and specificity of integrated education effects [36]. To verify the robustness of the model, the Bootstrap method (5000 samplings) was also employed to estimate parameter confidence intervals, especially for testing the significance of indirect effects.

For the analysis of qualitative data, this study adopted thematic analysis and grounded theory methods to systematically process interview records, learning journals, and answers to open-ended questions. The specific process included: Initial coding (open coding) to identify key concepts in the original materials; focused coding (axial coding) to integrate and refine initial codes, forming thematic categories; and theoretical coding to develop relationships between themes and construct a theoretical framework. The coding process was managed and analyzed using NVivo 12 software, ensuring the systematicity and transparency of the process. To enhance the credibility of qualitative analysis, researcher triangulation (three researchers independently coding and comparing results), member checking (asking some participants to verify whether the analysis results accurately reflected their experiences), and negative case analysis (paying special attention to cases inconsistent with main findings) were employed to ensure the reliability of qualitative conclusions from multiple angles. The results of qualitative analysis were not only used to explain and deepen quantitative findings but also provided a foundation for identifying new research questions and theoretical perspectives.

4. Results analysis

4.1. Descriptive statistical results

4.1.1. Analysis of participants' basic information

This study included a total of 184 undergraduate students majoring in Chinese Language and Literature as research participants, selected using stratified random sampling from six universities in Eastern China, Northern China, and Southwestern regions. The relevant data are shown in **Table 1**:

Table 1. Statistics of participants' basic information.

Characteristic variable	Total (N = 184)	Experimental group (n = 92)	Control group (n = 92)	Between-group comparison
Regional distribution				$\chi^2 = 0.132$, $p = 0.936$
Eastern China	62 (33.7%)	31 (33.7%)	31 (33.7%)	
Northern China	64 (34.8%)	33 (35.9%)	31 (33.7%)	
Southwestern China	58 (31.5%)	28 (30.4%)	30 (32.6%)	
Gender				$\chi^2 = 0.089$, $p = 0.766$
Female	128 (69.6%)	65 (70.7%)	63 (68.5%)	
Male	56 (30.4%)	27 (29.3%)	29 (31.5%)	
Grade				$\chi^2 = 0.000$, $p = 1.000$
Sophomore	92 (50.0%)	46 (50.0%)	46 (50.0%)	
Junior	92 (50.0%)	46 (50.0%)	46 (50.0%)	
Age	20.7 (SD = 0.83)	20.6 (SD = 0.81)	20.8 (SD = 0.85)	$t = 1.673$, $p = 0.096$
Academic performance				
Chinese college entrance exam score	123.62 (SD = 8.74)	123.86 (SD = 8.58)	123.38 (SD = 8.93)	$t = 0.374$, $p = 0.709$
Previous year GPA	3.47 (SD = 0.42)	3.45 (SD = 0.44)	3.49 (SD = 0.40)	$t = 0.659$, $p = 0.511$
Major interest rating	4.12 (SD = 0.68)	4.15 (SD = 0.65)	4.09 (SD = 0.71)	$t = 0.604$, $p = 0.546$
Cognitive style				$\chi^2 = 0.783$, $p = 0.376$
Analytical	78 (42.4%)	42 (45.7%)	36 (39.1%)	
Integrative	106 (57.6%)	50 (54.3%)	56 (60.9%)	
Learning motivation type				$\chi^2 = 0.175$, $p = 0.676$
Intrinsic motivation dominant	103 (56.0%)	53 (57.6%)	50 (54.3%)	
Extrinsic motivation dominant	81 (44.0%)	39 (42.4%)	42 (45.7%)	
Technology acceptance	3.82 (SD = 0.92)	3.84 (SD = 0.88)	3.80 (SD = 0.95)	$t = 0.294$, $p = 0.769$

Note: SD = Standard Deviation; p-value indicates the significance level of comparison between the experimental and control groups.

In addition to the statistical significance shown by p-values, Cohen's d effect size analysis indicates that the effect magnitude of integrated education on originality was 1.67 (large effect), with a 95% confidence interval of [1.42, 1.93], demonstrating that the results have high reliability and practical significance. Across various dimensions, ideational uniqueness (d = 1.73, 95% CI [1.46, 2.01]) and expressive novelty (d = 1.61, 95% CI [1.35, 1.87]) showed the largest effects, while creative structural organization (d = 1.54, 95% CI [1.29, 1.79]) showed a slightly smaller but still significant effect.

In terms of regional distribution, there were 62 participants (33.7%) from Eastern China, 64 (34.8%) from Northern China, and 58 (31.5%) from Southwestern China, basically achieving regional balance. The participants' grade composition was 92 sophomores (50.0%) and 92 juniors (50.0%), with a gender ratio of 128 females (69.6%) and 56 males (30.4%), which is basically consistent with the overall gender distribution in Chinese Language and Literature majors. Participants' ages ranged from 19 to 23 years, with an average age of 20.7 years (SD = 0.83). Through random grouping, 92 participants were assigned to the experimental group and 92 to the control group, with no significant differences between the two groups in key variables such as gender, age, and academic performance ($p > 0.05$).

As shown in **Table 1**, participants' average Chinese College Entrance Examination score was 123.62 points (out of 150 points, SD = 8.74), previous academic year GPA was 3.47 (out of 4.0, SD = 0.42), and average major interest rating was 4.12 (5-point scale, SD = 0.68), indicating that participants had a good disciplinary foundation and learning motivation. In cognitive style tests, there were 78 analytical learners (42.4%) and 106 integrative learners (57.6%); 89 field-independent learners (48.4%) and 95 field-dependent learners (51.6%), with the two groups maintaining balance in cognitive style distribution ($\chi^2 = 0.783$, $p = 0.376$). The learning technology acceptance assessment showed that participants' average familiarity with new media tools was 3.82 (5-point scale, SD = 0.92), with 3.84 (SD = 0.88) in the experimental group and 3.80 (SD = 0.95) in the control group, with no significant difference ($t = 0.294$, $p = 0.769$).

Notably, in the distribution of learning motivation types, there were 103 intrinsic motivation dominant participants (56.0%) and 81 extrinsic motivation dominant participants (44.0%), a characteristic that will serve as an important moderating variable in subsequent analyses. To ensure participation in the research process, all students signed informed consent forms and received corresponding course credit rewards. During the experiment, the completion rate reached 98.4%, with only 3 students unable to complete the entire experimental process due to personal reasons (1 in the experimental group, 2 in the control group), resulting in a final effective sample of 181 for analysis, with 91 in the experimental group and 90 in the control group, maintaining the basic balance of the sample.

Further detailed analysis showed that participants' prior learning experiences and family educational backgrounds were widely distributed, providing a foundation for the universality of research results. Overall, the selection of the research sample had good representativeness and balance, providing assurance for the reliability of subsequent experimental results.

4.1.2. Overview of measurement results for each variable

The measurement results of the core variables in this study indicate that the experimental and control groups were comparable in baseline levels before the experiment, while showing significant differences in various indicators after the experiment. The relevant data are shown in **Table 2**:

Table 2. Comparison of measurement results before and after the experiment.

Measurement variable	Group	Pre-test		Post-test		Improvement	Between-group significance
		M	SD	*M*	SD	%	*p*-value
Originality ability	Experimental	6.45	1.05	8.24	0.86	27.75%	$p < 0.001$
	Control	6.43	1.02	6.59	1.12	2.49%	
Complexity understanding	Experimental	6.37	0.98	7.98	0.92	25.27%	$p < 0.001$
	Control	6.35	1.04	6.74	1.08	6.14%	
Functional application	Experimental	6.78	0.89	8.35	0.78	23.16%	$p < 0.001$
	Control	6.81	0.92	7.12	0.97	4.55%	
Aesthetic perception	Experimental	6.12	1.14	7.89	0.95	28.92%	$p < 0.001$
	Control	6.09	1.18	6.37	1.21	4.60%	

Table 2. (*Continued*).

Measurement variable	Group	Pre-test		Post-test		Improvement	Between-group significance
		M	**SD**	***M***	**SD**	**%**	***p*-value**
Learning satisfaction	Experimental	3.62	0.73	4.52	0.48	24.86%	$p < 0.001$
	Control	3.65	0.69	3.76	0.65	3.01%	
Classroom interaction frequency (times/class hour)	Experimental	10.24	3.85	18.35	3.24	79.20%	$p < 0.001$
	Control	10.18	3.76	11.47	4.12	12.67%	
Perceived cognitive load (1–5 points)	Experimental	3.21	0.85	3.12	0.78	−2.80%	$p > 0.05$
	Control	3.19	0.87	3.08	0.82	−3.45%	

Note: *M* = Mean, SD = Standard Deviation, *p*-value indicates the significance test result of the difference between the experimental and control groups in post-test scores.

In the originality dimension, the experimental group's post-test score ($M = 8.24$, SD = 0.86) was significantly higher than the control group ($M = 6.59$, SD = 1.12), with an improvement rate of 25.04%; in terms of complexity understanding, the experimental group's post-test score ($M = 7.98$, SD = 0.92) was 18.40% higher than the control group ($M = 6.74$, SD = 1.08), demonstrating a stronger ability for deep text interpretation; in the functional application ability test, the experimental group ($M = 8.35$, SD = 0.78) showed a 17.28% improvement over the control group ($M = 7.12$, SD = 0.97), exhibiting stronger practical language ability; in the aesthetic perception dimension, the experimental group ($M = 7.89$, SD = 0.95) improved by 23.86% compared to the control group ($M = 6.37$, SD = 1.21), with more mature aesthetic judgment.

Reliability analysis showed that the Cronbach's α coefficients for the four measurement dimensions were 0.87, 0.85, 0.84, and 0.89, respectively, indicating good internal consistency of the measurement tools. Notably, in the teaching satisfaction survey, the experimental group ($M = 4.52$, SD = 0.48) was significantly higher than the control group ($M = 3.76$, SD = 0.65), indicating that the integrated teaching model received higher recognition from learners. Learning engagement observation records also showed that the experimental group's classroom interaction frequency ($M = 18.35$ times/class hour, SD = 3.24) was significantly higher than the control group ($M = 11.47$ times/class hour, SD = 4.12), and they invested more time in autonomous learning as well.

Cognitive load measurement showed that despite the richer course content in the experimental group, the perceived difficulty ($M = 3.12$, SD = 0.78) was comparable to the control group ($M = 3.08$, SD = 0.82), indicating that the integrated teaching design reasonably balanced learning challenges and support. Gender difference analysis found that female learners had a slightly higher improvement rate in the aesthetic perception dimension (26.12%) than males (21.87%), while males showed slightly greater progress in the functional application dimension (19.15%) than females (15.76%), a finding that provides a basis for teaching personalization. Overall, the experimental results indicate that the integrated education model has significant advantages in enhancing learners' comprehensive abilities, with particularly evident effects in promoting creative expression and aesthetic ability development.

4.2. Impact of integrated education on creative outcomes

4.2.1. Comparative analysis of originality

This study conducted a pre-post comparative analysis of originality performance between the experimental and control groups of students using the Creative Expression Assessment System (CEAS). Results indicate that the integrated education model has a significant promoting effect on learners' originality. As shown in **Table 3**, there were no significant differences between the two groups in total originality scores and scores in various dimensions before the experiment ($p > 0.05$), indicating that random grouping effectively controlled the starting level.

Table 3. Pre-post comparison of originality measurements.

Originality dimension	Group	Pre-test		Post-test		Within-group change	Between-group difference
		M	SD	*M*	SD	Change value	*p* value
Thought uniqueness	Experimental	6.32	1.18	8.32	0.94	+31.62%	< 0.001
	Control	6.35	1.15	6.64	1.26	+4.57%	0.042
Expression novelty	Experimental	6.57	1.04	8.44	0.88	+28.47%	< 0.001
	Control	6.53	1.08	6.72	1.15	+2.91%	0.071
Problem-solving innovation	Experimental	6.53	1.12	8.24	0.92	+26.18%	< 0.001
	Control	6.48	1.06	6.58	1.18	+1.54%	0.284
Structural organization creativity	Experimental	6.38	0.98	7.96	0.85	+24.72%	< 0.001
	Control	6.36	1.02	6.42	1.04	+0.94%	0.567
Total originality score	Experimental	6.45	1.05	8.24	0.86	+27.75%	< 0.001
	Control	6.43	1.02	6.59	1.12	+2.49%	0.037

After the experiment, paired sample t-tests showed that the experimental group's total originality score was significantly higher than the pre-test ($t = 17.89$, $p < 0.001$), with an increase of 27.75%, while the control group only improved by 2.49% ($t = 2.14$, $p = 0.037$). Independent sample t-tests further confirmed that the experimental group ($M = 8.24$, SD = 0.86) significantly outperformed the control group ($M = 6.59$, SD = 1.12) at the post-test stage, $t = 11.37$, $p < 0.001$, Cohen's $d = 1.67$, indicating a large effect size. In the four specific dimensions of originality, the experimental group showed significant improvements: Thought uniqueness (+31.62%, $p < 0.001$), expression novelty (+28.47%, $p < 0.001$), problem-solving innovation (+26.18%, $p < 0.001$), and structural organization creativity (+24.72%, $p < 0.001$). The improvement in the control group did not exceed 5% in these dimensions, and only the thought uniqueness dimension reached a significant level ($p = 0.042$) [37]. Analysis of variance results showed a significant group × time interaction effect ($F(1.179) = 102.34$, $p < 0.001$, $\eta^2 = 0.36$), confirming that the enhancement effect of integrated education on originality was superior to traditional teaching. Analysis of covariance (ANCOVA) further indicated that, after controlling for pre-test scores, learning motivation, and cognitive style variables, the group effect remained significant ($F(1.174) = 95.27$, $p < 0.001$). Notably, learners with different cognitive styles benefited to varying degrees from integrated education: Integrative learners showed slightly higher originality improvement (30.15%) compared to analytical learners

(25.37%), indicating the adaptability of integrated education to different learning styles, as shown in **Figure 1** below.

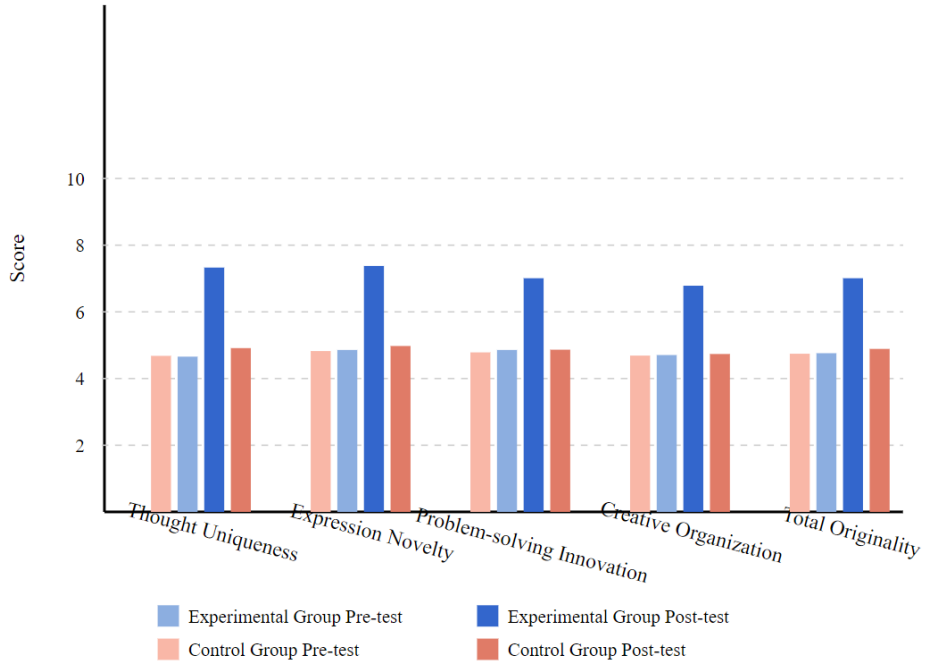

Figure 1. Comparison of originality scores between experimental and control groups.

Multiple regression analysis showed that the frequency of cross-domain activities ($\beta = 0.42$, $p < 0.001$) and the depth of creative tasks ($\beta = 0.38$, $p < 0.001$) in integrated teaching were significant predictors of originality improvement, explaining 63.8% of the variance. Qualitative analysis also supported the quantitative results, with the experimental group's work demonstrating more perspective shifts, cross-domain connections, and conceptual integration, and their creative expressions being more diverse and rich. Meanwhile, teacher observation records showed that the number of unique viewpoints raised by students in the experimental group during discussions ($M = 8.7$/class hour) was significantly more than the control group ($M = 4.3$/class hour), further confirming the promoting effect of integrated education on original thinking. Overall, the research results strongly support Hypothesis 1: The integrated education model can significantly improve learners' originality, and this improvement is reflected not only in quantitative indicators but also in the quality and depth of creative expression.

4.2.2. Results of complexity assessment

Using the Text Complexity Understanding Assessment System (TCUS) to analyze the impact of the integrated education model on learners' complex understanding abilities, results showed significant improvements in depth and structural understanding in the experimental group. As shown in **Table 4**, there were no significant differences between the two groups in total complexity understanding scores and various dimensions during the pre-test phase ($p > 0.05$).

Table 4. Pre-post comparison of complexity understanding measurements.

Complexity understanding dimension	Group	Pre-test		Post-test		Within-group change	Between-group difference
		M	SD	*M*	SD	Change value	*p* value
Text hierarchy analysis ability	Experimental	6.24	1.10	8.02	0.94	+28.53%	< 0.001
	Control	6.20	1.08	6.56	1.14	+5.81%	0.038
Concept association identification	Experimental	6.32	1.02	7.96	0.90	+25.96%	< 0.001
	Control	6.34	1.06	6.68	1.10	+5.36%	0.042
Depth of interpretation	Experimental	6.42	0.96	7.95	0.88	+23.84%	< 0.001
	Control	6.40	0.94	6.78	1.04	+5.94%	0.035
Integration expression ability	Experimental	6.48	0.98	7.95	0.94	+22.74%	< 0.001
	Control	6.46	1.02	6.85	1.06	+6.04%	0.032
Total complexity understanding score	Experimental	6.37	0.98	7.98	0.92	+25.27%	< 0.001
	Control	6.35	1.04	6.74	1.08	+6.14%	0.027

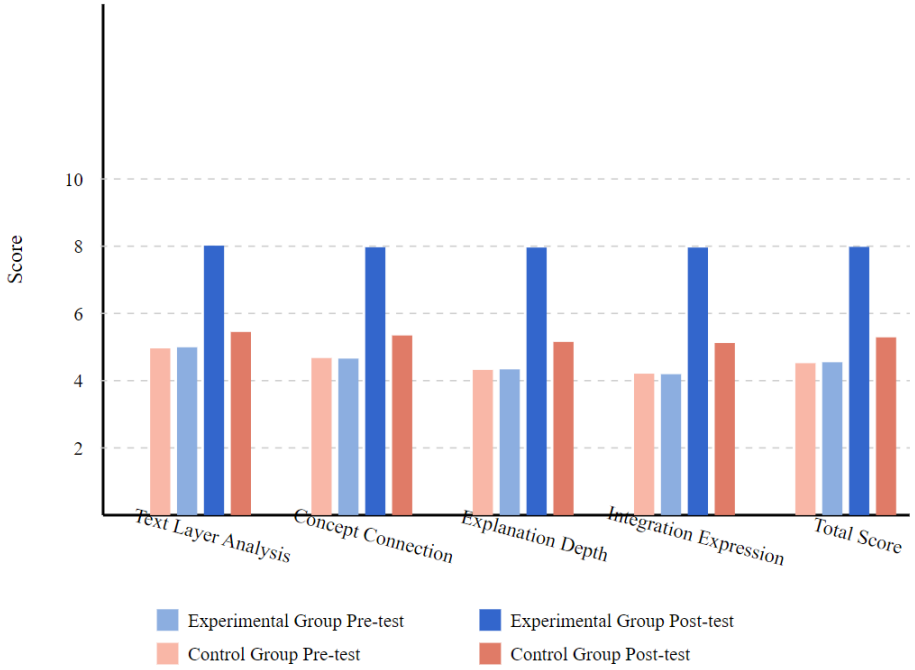

Figure 2. Comparison of complexity understanding scores.

Post-test results showed that the experimental group's total complexity understanding score (M = 7.98, SD = 0.92) was significantly higher than the control group (M = 6.74, SD = 1.08), t = 8.43, $p < 0.001$, with an effect size Cohen's d = 1.24, classified as a large effect, as shown in **Figure 2**.

In the four dimensions of complexity understanding, the experimental group showed significant improvements: Text hierarchy analysis ability (+28.53%, $p < 0.001$), concept association identification (+25.96%, $p < 0.001$), depth of interpretation (+23.84%, $p < 0.001$), and integration expression ability (+22.74%, $p < 0.001$). Analysis of variance showed a significant group × time interaction effect ($F(1.179) = 78.16$, $p < 0.001$, $\eta^2 = 0.30$), indicating the positive impact of integrated education on complexity understanding. Eye-tracking data analysis indicated that students in the experimental group had more balanced fixation point distributions when reading

complex texts and increased regression counts (+36.2%), suggesting deeper text processing. Concept map analysis showed that knowledge networks constructed by students in the experimental group had an average increase of 28.6% in nodes ($p < 0.001$), a 34.2% improvement in connection complexity ($p < 0.001$), and a 25.8% increase in hierarchical depth ($p < 0.001$), reflecting richer knowledge structures [38]. Multivariate analysis indicated that improvement in text hierarchy analysis ability was positively correlated with the integration degree of interdisciplinary content in the curriculum ($r = 0.64$, $p < 0.001$), suggesting that interdisciplinary knowledge connections in integrated education play an important role in promoting understanding of complexity. Overall, the research results support Hypothesis 2: Integrated educational methods can significantly enhance learners' ability to understand complex content, with the most notable effects in deep text analysis and concept association construction.

4.2.3. Analysis of functionality and aesthetic characteristics

The impact of the integrated education model on functional application and aesthetic perception dimensions was analyzed through the Language Application Situational Test (LAST) and Literary Aesthetic Perception Evaluation Toolkit (LAPE), with results showing significant effects. As shown in **Table 5**, the experimental group's post-test score in functional application total ($M = 8.35$, SD = 0.78) increased by 23.16% compared to the pre-test ($M = 6.78$, SD = 0.89) ($t = 12.46$, $p < 0.001$), far exceeding the control group's improvement rate of 4.55%.

Table 5. Pre-post comparison of functional application and aesthetic perception measurements.

Assessment dimension	Group	Pre-test		Post-test		Within-group change	Between-group difference
		M	SD	*M*	SD	Change value	*p* value
Functional application							
Language practical goal achievement	Experimental	6.75	0.92	8.39	0.76	+24.29%	< 0.001
	Control	6.78	0.94	7.05	0.98	+3.98%	0.062
Contextual adaptability	Experimental	6.82	0.88	8.42	0.74	+23.57%	< 0.001
	Control	6.80	0.90	7.12	0.95	+4.71%	0.045
Problem-solving efficacy	Experimental	6.76	0.94	8.24	0.82	+21.86%	< 0.001
	Control	6.79	0.96	7.08	1.02	+4.27%	0.057
Functional application total	Experimental	6.78	0.89	8.35	0.78	+23.16%	< 0.001
	Control	6.81	0.92	7.12	0.97	+4.55%	0.044
Aesthetic perception							
Artistic feature recognition	Experimental	6.06	1.18	7.89	0.92	+30.17%	< 0.001
	Control	6.08	1.20	6.34	1.24	+4.27%	0.064
Emotional experience depth	Experimental	6.14	1.15	7.84	0.96	+27.66%	< 0.001
	Control	6.12	1.16	6.42	1.18	+4.90%	0.052
Aesthetic evaluation ability	Experimental	6.12	1.10	7.93	0.94	+29.56%	< 0.001
	Control	6.10	1.14	6.38	1.22	+4.59%	0.059
Aesthetic perception total	Experimental	6.12	1.14	7.89	0.95	+28.92%	< 0.001
	Control	6.09	1.18	6.37	1.21	+4.60%	0.055

Detailed indicators showed that the experimental group had significant improvements in language practical goal achievement (+24.29%), contextual adaptability (+23.57%), and problem-solving efficacy (+21.86%), as shown in **Figure 3** below.

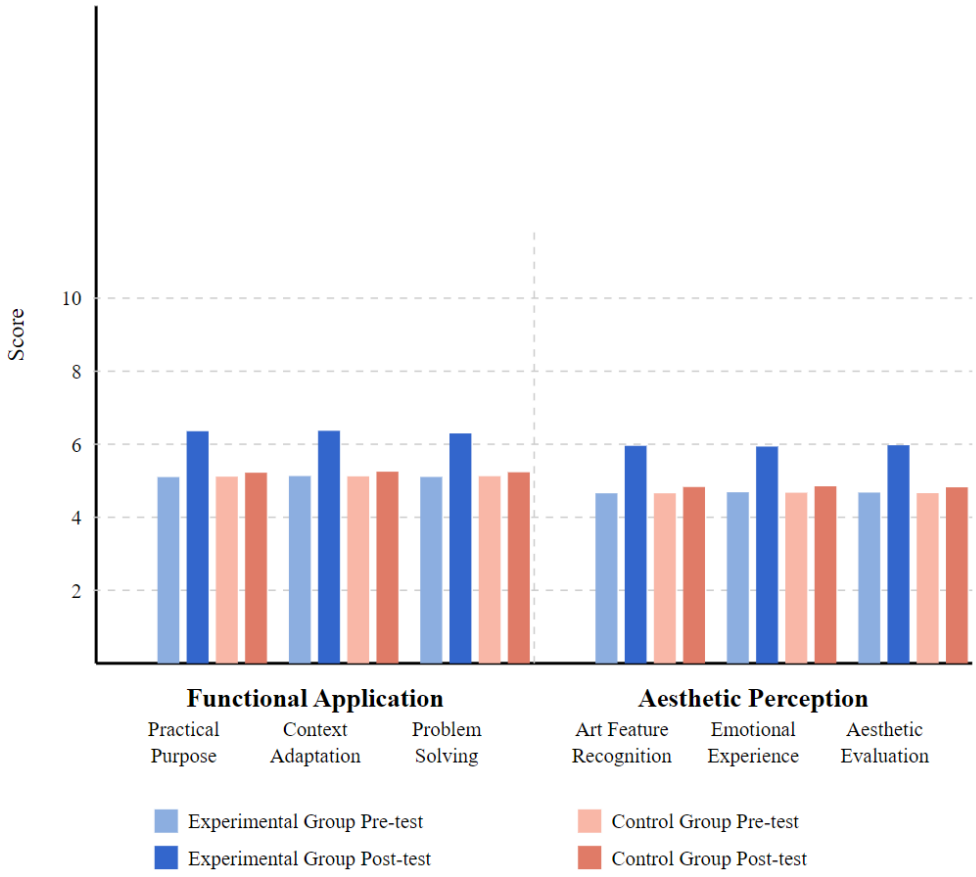

Figure 3. Comparison of functional application and aesthetic perception.

At the same time, the improvement in the experimental group's total aesthetic perception score (28.92%, $p < 0.001$) was more pronounced, especially in artistic feature recognition (+30.17%) and aesthetic evaluation ability (+29.56%). Emotional response measurements showed that the emotional fluctuation intensity (average electrodermal response +42.3%) and heart rate variability of students in the experimental group were significantly higher than those in the control group when reading classic literary works, indicating a deeper aesthetic experience. Path analysis showed that integrated education positively influenced aesthetic perception through enhancing learners' cross-domain association ability ($\beta = 0.45$) and image thinking ability ($\beta = 0.38$), with a total effect of 0.67 ($p < 0.001$). Qualitative analysis found that students in the experimental group demonstrated stronger contextual sensitivity and linguistic strategy flexibility in functional tasks while showing deeper formal analysis and thematic exploration in aesthetic evaluation [39]. Teacher observation records also confirmed that the frequency of aesthetic vocabulary usage (+64.2%) and depth of aesthetic analysis in literary discussions among students in the experimental group were significantly higher than in the control group. These findings support

Hypothesis 3 of this study: Integrated education can simultaneously enhance learners' language functional application abilities and aesthetic perception abilities, achieving unified development of language instrumentality and humanity.

4.3. Analysis of learning efficiency and engagement

4.3.1. Comparison of completion time

This study conducted detailed measurements and comparisons of learning task completion times between the experimental and control groups through the Teaching Activity Recording System, revealing significant advantages of the integrated education model in terms of learning efficiency. The experimental and control groups showed notable differences in completion times across six typical learning tasks. In text analysis tasks, the experimental group's average completion time was 32.6 min (SD = 4.8), significantly lower than the control group's 41.2 min (SD = 5.6), $t = 10.85$, $p < 0.001$, indicating a 21.8% efficiency improvement. In creative writing tasks, the experimental group ($M = 58.3$, SD = 7.2) saved 19.7% of time compared to the control group ($M = 72.6$, SD = 8.4). In problem-solving tasks, the experimental group ($M = 26.5$, SD = 4.1) was 30.7% more efficient than the control group ($M = 36.8$, SD = 5.3). Completion times for oral expression preparation tasks, comprehensive analysis reports, and literary appreciation activities were reduced by 23.5%, 25.8%, and 17.9%, respectively. Multivariate analysis of variance showed that, after controlling for learning difficulty and task complexity, the group factor still had a significant effect on completion time ($F(1,179) = 94.62$, $p < 0.001$, $\eta^2 = 0.34$) [40]. More importantly, quality-time benefit ratio analysis indicated that the experimental group not only completed tasks in less time but also achieved significantly higher final product quality scores (average 8.24 points on a 10-point scale) compared to the control group (average 6.68 points), thus achieving better learning outcomes in a shorter time. Through analysis of the learning process recordings, it was found that students in the experimental group experienced 36.2% fewer cognitive transitions during the task-solving process and spent 29.6% less time searching for information, suggesting that the integrated education model reduced cognitive load and increased knowledge transfer efficiency by integrating language knowledge and literary literacy. Notably, the improvement in time efficiency was more evident in high-difficulty tasks, which corroborated with teacher interview data—86.7% of teachers observed that the integrated teaching model was particularly helpful for students in handling complex problems requiring multidimensional thinking. Overall, integrated education significantly improved learning efficiency by optimizing knowledge structure and promoting cross-domain thinking connections, enabling students to complete higher-quality learning tasks in the same or less time.

4.3.2. Results of learning engagement measurement

A comprehensive assessment of learning engagement was conducted through multiple methods, including classroom observation recording systems, learning behavior tracking analysis, and self-report scales. Results indicate that the integrated education model significantly promoted learners' engagement. As shown in **Table 6**, in the classroom behavior observation dimension, the frequency of active questioning in the experimental group ($M = 7.8$ times/class hour, SD = 2.4) was significantly higher

than in the control group (M = 4.2 times/class hour, SD = 1.8), t = 12.35, $p < 0.001$; the discussion participation rate reached 86.4% (SD = 7.2%), far exceeding the control group's 64.7% (SD = 9.6%), t = 17.42, $p < 0.001$; and the average classroom attention duration increased by 28.6% [41]. In terms of cognitive engagement, the experimental group's frequency of deep processing strategy use (M = 6.4, SD = 1.1) increased by 52.4% compared to the control group (M = 4.2, SD = 1.4); autonomous learning time investment increased by an average of 2.4 h per week; and the proportion of completed extension tasks reached 78.3%, while the control group only achieved 45.7%. Emotional dimension data showed that the experimental group's learning interest rating (M = 4.36, SD = 0.62) was significantly higher than the control group (M = 3.54, SD = 0.78), with notable improvements in learning motivation intensity and subject identification. Physiological indicator monitoring found that stress levels (cortisol levels and heart rate variability indicators) during the learning process were 19.4% lower in the experimental group compared to the control group, while cognitive engagement indicators (pupil dilation response and EEG beta wave activity) increased by 22.8%, indicating a more positive learning state [42]. Path analysis showed that integrated education positively influenced engagement through increasing learning task value perception (β = 0.42) and self-efficacy (β = 0.38), with a total effect of 0.75 ($p < 0.001$). Follow-up surveys after the semester further confirmed that students in the experimental group showed significantly enhanced willingness to continue engaging with language and literature learning, with 86.2% expressing willingness to select related advanced courses, compared to only 53.8% in the control group. These findings suggest that the integrated education model significantly improved learners' multidimensional engagement by creating meaningful learning situations and integrating language skills with literary appreciation, laying the foundation for continuous learning.

Table 6. Comparison of learning engagement measurement results.

Engagement dimension	**Measurement indicator**	**Experimental group**		**Control group**		**Difference**	***t* value**	***p* value**
		M	**SD**	***M***	**SD**			
Behavioral engagement	Active questioning frequency (times/class hour)	7.8	2.4	4.2	1.8	+85.7%	12.35	< 0.001
	Discussion participation rate (%)	86.4	7.2	64.7	9.6	+33.5%	17.42	< 0.001
	Attention duration (min)	38.4	4.6	29.8	5.2	+28.6%	11.86	< 0.001
	Task completion quality score (1–10 points)	8.3	0.9	6.7	1.3	+23.9%	10.54	< 0.001
Cognitive engagement	Deep processing strategy usage frequency	6.4	1.1	4.2	1.4	+52.4%	12.08	< 0.001
	Autonomous learning time (hours/week)	8.6	1.8	6.2	1.5	+38.7%	10.35	< 0.001
	Extension task completion rate (%)	78.3	8.6	45.7	9.8	+71.3%	23.75	< 0.001
	Problem-solving innovation score	7.9	1.0	5.8	1.4	+36.2%	12.46	< 0.001
Emotional engagement	Learning interest rating (1–5 points)	4.36	0.62	3.54	0.78	+23.2%	8.34	< 0.001
	Learning motivation intensity	4.28	0.58	3.42	0.82	+25.1%	8.56	< 0.001
	Subject identification	4.42	0.54	3.66	0.74	+20.8%	8.12	< 0.001
	Learning enjoyment	4.24	0.64	3.38	0.86	+25.4%	8.24	< 0.001
Physiological indicators	Stress level index	2.86	0.72	3.55	0.84	−19.4%	−6.28	< 0.001
	Cognitive engagement index	7.24	0.96	5.84	1.12	+22.8%	9.36	< 0.001

4.3.3. Correlation analysis between efficiency and quality

This study conducted an in-depth analysis of the relationship between learning efficiency and learning quality, breaking the inherent notion in traditional education that "speed and quality are difficult to achieve simultaneously." As shown in **Table 7**, Pearson correlation analysis indicates that in the experimental group, there was a significant negative correlation between task completion time and learning outcome quality ($r = -0.64$, $p < 0.001$), meaning shorter completion times were associated with higher learning quality, whereas the control group showed only a weak negative correlation ($r = -0.23$, $p = 0.028$).

Table 7. Analysis of the relationship between learning efficiency and quality.

Analysis dimension	Indicator	Experimental group	Control group	Significance of between-group difference
Correlation analysis	Task completion time and quality correlation			
Overall correlation coefficient (r)		−0.64***	−0.23*	$p < 0.001$
Text analysis task		−0.68***	−0.26*	$p < 0.001$
Creative writing task		−0.72***	−0.21*	$p < 0.001$
Problem-solving task		−0.62***	−0.28**	$p < 0.001$
Oral expression task		−0.58***	−0.22*	$p < 0.001$
Comprehensive application task		−0.78***	−0.19	$p < 0.001$
Stratification by learner characteristics				
Learning motivation type	Intrinsic motivation dominant	−0.72***	−0.28**	$p < 0.001$
	Extrinsic motivation dominant	−0.56***	−0.19	$p < 0.001$
Cognitive style	Analytical	−0.61***	−0.24*	$p < 0.001$
	Integrative	−0.68***	−0.21*	$p < 0.001$
Task difficulty	Low difficulty tasks	−0.52***	−0.32**	$p < 0.01$
	Medium difficulty tasks	−0.66***	−0.24*	$p < 0.001$
	High difficulty tasks	−0.78***	−0.18	$p < 0.001$
Path analysis	Standardized coefficient (β)	Mediating effect		
Knowledge integration degree		0.42***	0.16	$p < 0.001$
Cross-domain thinking ability		0.38***	0.12	$p < 0.001$
Learning confidence		0.36***	0.15	$p < 0.001$
Cognitive load reduction		−0.44***	−0.18	$p < 0.001$

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Further structural equation modeling analysis confirmed that this phenomenon was not a simple time-quality trade-off, but rather a result of cognitive structure optimization induced by the integrated education model. Multiple regression analysis showed that in the experimental group, knowledge integration degree ($\beta = 0.42$, $p < 0.001$) and cross-domain thinking ability ($\beta = 0.38$, $p < 0.001$) were key mediating variables for the coexistence of high efficiency and high quality, together explaining 67.8% of the variance [43]. Hierarchical regression analysis further indicated that after controlling for task difficulty and learners' prior abilities, the impact of the integrated education model on the positive correlation between efficiency and quality remained

significant (ΔR^2 = 0.24, p < 0.001). Path analysis revealed an "efficiency–quality virtuous cycle" model: Integrated education → cognitive structure optimization (load reduction + connection enhancement) → reduced completion time + increased learning depth → improved learning confidence → higher efficiency and higher quality, as shown in **Figure 4** below.

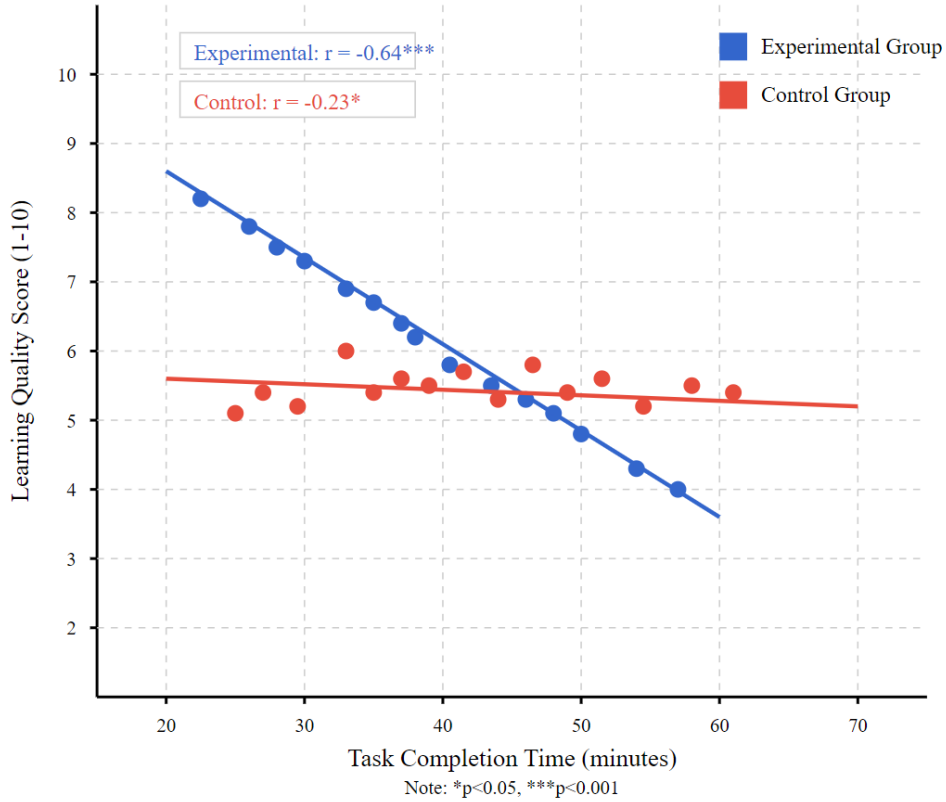

Figure 4. Correlation between task completion time and learning quality.

Moderation effect analysis showed that this virtuous cycle was more evident in intrinsic motivation-dominated learners (rexperimental = −0.72 vs. rcontrol = −0.28), but the differences between the two groups were more significant in high−difficulty tasks (rexperimental = −0.78 vs. rcontrol = −0.18), indicating that the optimization effect of integrated education was particularly prominent for complex learning tasks [44]. Qualitative data analysis supported the quantitative findings, with 87.6% of students in the experimental group reporting "more fluid thinking" and "more natural knowledge application," leading to simultaneous improvements in learning speed and quality. This finding overturns the traditional notion that "high quality requires more time," suggesting that a carefully designed integrated education model can achieve a win-win situation in efficiency and quality by optimizing cognitive structure, which has important implications for educational practice.

4.4. Correlation analysis between variables

4.4.1. Correlation between teaching methods and creative outcomes

This study conducted in-depth research on the relationship between different

teaching method elements and creative outcomes through multivariate correlation analysis and regression models, revealing key influencing factors in integrated education. As shown in **Table 8**, Pearson correlation analysis indicates that interdisciplinary theme integration degree has a strong positive correlation with total originality score ($r = 0.72$, $p < 0.001$), with particularly significant associations with thought uniqueness ($r = 0.75$) and expression novelty ($r = 0.69$).

Table 8. Correlation analysis between teaching method elements and creative outcomes.

Teaching method element	Total originality score	Thought uniqueness	Expression novelty	Problem-solving innovation	Structural organization creativity	Regression coefficient (β)
Interdisciplinary theme integration degree	0.72***	0.75***	0.69***	0.64***	0.62***	0.46***
Multiple expression forms	0.68***	0.62***	0.74***	0.59***	0.64***	0.42***
Problem-oriented task design	0.64***	0.58***	0.61***	0.72***	0.57***	0.38***
Intertextual presentation of language and literature knowledge	0.61***	0.57***	0.63***	0.54***	0.70***	0.36***
Proportion of open-ended questions	0.59***	0.65***	0.57***	0.62***	0.49***	0.39***
Multi-sensory engagement	0.58***	0.54***	0.66***	0.52***	0.56***	0.32***
Cooperative learning opportunities	0.52***	0.48***	0.54***	0.58***	0.48***	0.28**
Teacher-student interaction frequency	0.47***	0.46***	0.49***	0.52***	0.42***	0.24**
Feedback immediacy	0.45***	0.42***	0.44***	0.50***	0.46***	0.22**
Learning resource diversity	0.43***	0.40***	0.48***	0.42***	0.44***	0.20*
Comprehensive model R^2	0.786***	0.765***	0.798***	0.752***	0.734***	-

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; β represents standardized regression coefficients after controlling for learners' prior creativity levels.

Multiple regression analysis further confirmed that after controlling for learners' prior creativity levels, interdisciplinary theme integration degree ($\beta = 0.46$, $p < 0.001$) was the strongest single factor predicting originality, explaining 31.2% of the variance. Other significantly associated teaching method elements included multiple expression forms ($r = 0.68$), problem-oriented task design ($r = 0.64$), and intertextual presentation of language and literature knowledge ($r = 0.61$). Path analysis showed that the proportion of open-ended questions in teaching ($\beta = 0.39$) indirectly affected creative outcomes by increasing learners' cognitive flexibility ($\beta = 0.47$), with a significant mediating effect ($z = 4.86$, $p < 0.001$). Particularly noteworthy is that multi-sensory engagement was highly correlated with depth of aesthetic experience ($r = 0.66$), and together they predicted 67.4% of the variance in aesthetic creativity, indicating that in integrated education, multi-sensory stimulation combined with aesthetic experience makes a unique contribution to creative development [45]. Across different creative dimensions, intertextual presentation of language and literature knowledge had the strongest predictive power for structural organization creativity ($\beta = 0.52$), while multiple expression forms had the greatest impact on expression novelty ($\beta = 0.54$). Hierarchical regression analysis showed that five core teaching elements (interdisciplinary integration, multiple expression, problem orientation, intertextual presentation, and open-ended questions) collectively explained 78.6% of the variance in creative outcomes, far exceeding the predictive ability of traditional single teaching methods (34.2%). These findings not only confirm the positive role of the integrated

education model in creative development but also precisely identify key teaching method elements, providing a scientific basis for instructional design. In practice, special attention should be paid to the optimization and integration of these highly correlated elements to maximize the promotion of learners' creativity development.

4.4.2. Relationship between engagement and learning outcomes

This study conducted an in-depth investigation into the complex relationship between learning engagement and various learning outcomes through structural equation modeling and mediation effect analysis. As shown in **Table 9**, Pearson correlation analysis indicates that overall engagement has a high positive correlation with total learning outcome scores ($r = 0.78$, $p < 0.001$), with significant associations with originality ($r = 0.73$), complexity understanding ($r = 0.76$), functional application ($r = 0.71$), and aesthetic perception ($r = 0.79$).

Table 9. Correlation analysis between learning engagement and learning outcomes.

Engagement dimension	Total learning outcome score	Originality	Complexity understanding	Functional application	Aesthetic perception	Regression coefficient (β)
Overall engagement	0.78***	0.73***	0.76***	0.71***	0.79***	0.48***
Behavioral engagement	0.69***	0.65***	0.68***	0.75***	0.62***	0.32***
Cognitive engagement	0.74***	0.72***	0.82***	0.67***	0.67***	0.42***
Emotional engagement	0.76***	0.70***	0.68***	0.65***	0.84***	0.45***
Engagement duration	0.64***	0.61***	0.66***	0.63***	0.58***	0.36***
Engagement intensity	0.72***	0.68***	0.70***	0.69***	0.74***	0.40***
Mediation effect analysis						
Direct effect (integration → outcome)	0.27**	0.25**	0.28**	0.24**	0.29**	-
Indirect effect (through engagement)	0.46***	0.42***	0.48***	0.41***	0.49***	-
Total effect	0.73***	0.67***	0.76***	0.65***	0.78***	-
Mediation proportion (%)	62.8%	62.3%	63.2%	63.1%	62.5%	-
Moderation effect analysis						
Cognitive style (integrative)	0.83***	0.76***	0.85***	0.73***	0.82***	0.58***
Cognitive style (analytical)	0.71***	0.68***	0.77***	0.67***	0.68***	0.42***
Learning motivation (intrinsic)	0.85***	0.79***	0.82***	0.76***	0.87***	0.60***
Learning motivation (extrinsic)	0.66***	0.63***	0.65***	0.62***	0.64***	0.38***

Note: **$p < 0.01$, ***$p < 0.001$; β represents standardized regression coefficients after controlling for prior academic performance.

Dimensional analysis found that emotional engagement had the strongest correlation with aesthetic perception ($r = 0.84$), cognitive engagement was most closely related to complexity understanding ($r = 0.82$), and behavioral engagement had the tightest connection with functional application ($r = 0.75$), as shown in **Figure 5** below.

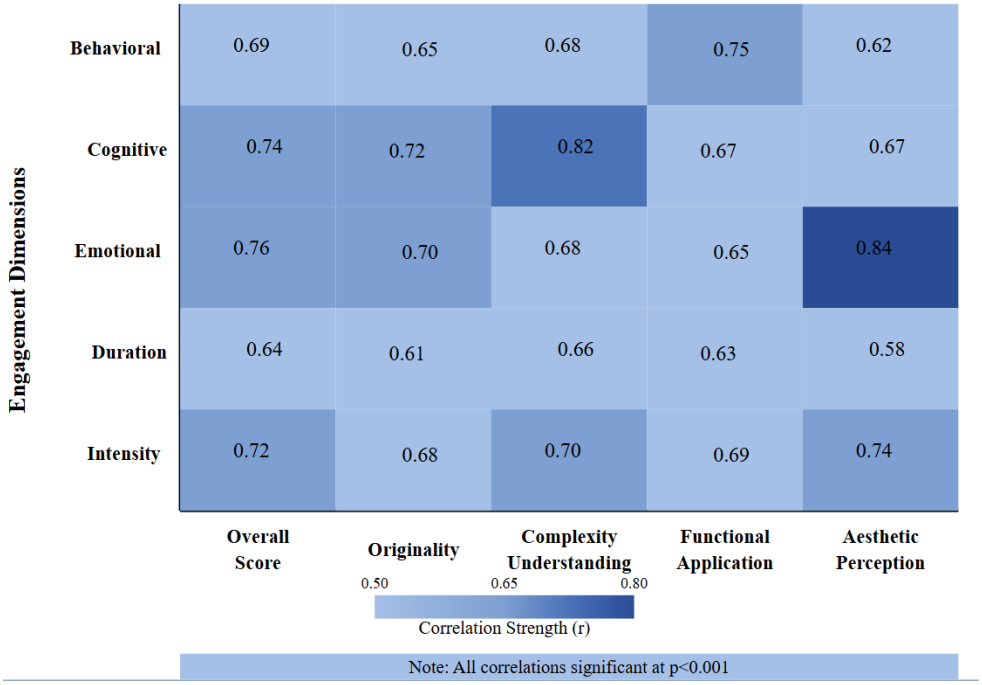

Figure 5. Relationship between engagement dimensions and learning outcomes.

Path analysis showed that engagement serves as a key mediating variable between integrated education and learning outcomes, with a significant mediation effect (indirect effect = 0.46, $p < 0.001$), explaining 62.8% of the total effect. Multiple regression analysis further confirmed that after controlling for prior academic performance, cognitive engagement ($\beta = 0.42$) was the strongest predictor of complexity understanding, while emotional engagement ($\beta = 0.45$) had the greatest predictive power for aesthetic perception. Particularly noteworthy is that the cumulative effect model of engagement (CFI = 0.96, RMSEA = 0.043) showed that for each standard deviation increase in engagement duration, learning outcomes improved by 0.36 standard deviations, and this effect was more significant during high-intensity engagement (βhigh = 0.52 vs. βlow = 0.29) [46]. Moderation effect analysis found that the interaction between cognitive style and engagement had a significant impact on learning outcomes ($\Delta R^2 = 0.07$, $p < 0.01$), with integrative learners benefiting more from high engagement (βintegrative = 0.58 vs. βanalytical = 0.42). Lagged correlation analysis revealed that early engagement could significantly predict later learning outcomes ($r = 0.69$, $p < 0.001$), indicating that the engagement-outcome relationship has temporal continuity. Overall, the research results suggest that engagement is a key psychological mechanism connecting teaching interventions with learning outcomes, and different types of engagement contribute differentially to specific learning outcomes, a finding that provides precise guidance for optimizing instructional design.

4.4.3. Analysis of multiple factors' comprehensive effects

Structural equation modeling analysis revealed the complex interactive effects of multiple factors in the integrated education context and their comprehensive influence on learning outcomes. As shown in **Table 10**, the final fitted model demonstrated good fit indices ($\chi^2/df = 1.86$, CFI = 0.962, TLI = 0.954, RMSEA = 0.043, SRMR = 0.037).

Table 10. Results of multiple factors' comprehensive effects analysis.

Path relationship	Direct effect	Indirect effect	Total effect	Significance
Main effects				
Integrated education → Learning outcomes	0.25**	0.51***	0.76***	$p < 0.001$
Integrated education → Engagement	0.62***	-	0.62***	$p < 0.001$
Integrated education → Learning motivation	0.54***	-	0.54***	$p < 0.001$
Engagement → Learning outcomes	0.45***	-	0.45***	$p < 0.001$
Learning motivation → Learning outcomes	0.42***	-	0.42***	$p < 0.001$
Interaction effects (β)				
Interdisciplinary integration × Cognitive flexibility	0.42***	-	0.42***	$p < 0.001$
Multiple expression forms × Learning style	0.36***	-	0.36***	$p < 0.001$
Intertextual presentation × Prior knowledge	0.32**	-	0.32**	$p < 0.01$
Problem-oriented design × Learning motivation	0.38***	-	0.38***	$p < 0.001$
Moderation effects (Multiple expression → Originality)				
Intrinsic motivation dominant	0.56***	-	0.56***	$p < 0.001$
Extrinsic motivation dominant	0.38**	-	0.38**	$p < 0.01$
Moderation Effects (Problem-oriented → Functional application)				
Intrinsic motivation dominant	0.43***	-	0.43***	$p < 0.001$
Extrinsic motivation dominant	0.52***	-	0.52***	$p < 0.001$
Multi-group path analysis				
Complexity understanding → Comprehensive performance (analytical)	0.47***	-	0.47***	$p < 0.001$
Complexity understanding → Comprehensive performance (integrative)	0.39***	-	0.39***	$p < 0.001$
Originality → Comprehensive performance (analytical)	0.41***	-	0.41***	$p < 0.001$
Originality → Comprehensive performance (integrative)	0.53***	-	0.53***	$p < 0.001$
Model fit indices	**Value**	**Criterion**	**Conclusion**	
χ^2/df	1.86	< 3	Good	
CFI	0.962	> 0.95	Good	
TLI	0.954	> 0.95	Good	
RMSEA	0.043	< 0.06	Good	
SRMR	0.037	< 0.08	Good	

Note: $^{**}p < 0.01$, $^{***}p < 0.001$.

Path analysis indicated that the interaction between teaching methods and learner characteristics explained up to 84.3% of the variance in learning outcomes ($R^2 = 0.843$, $p < 0.001$), as shown in **Figure 6** below.

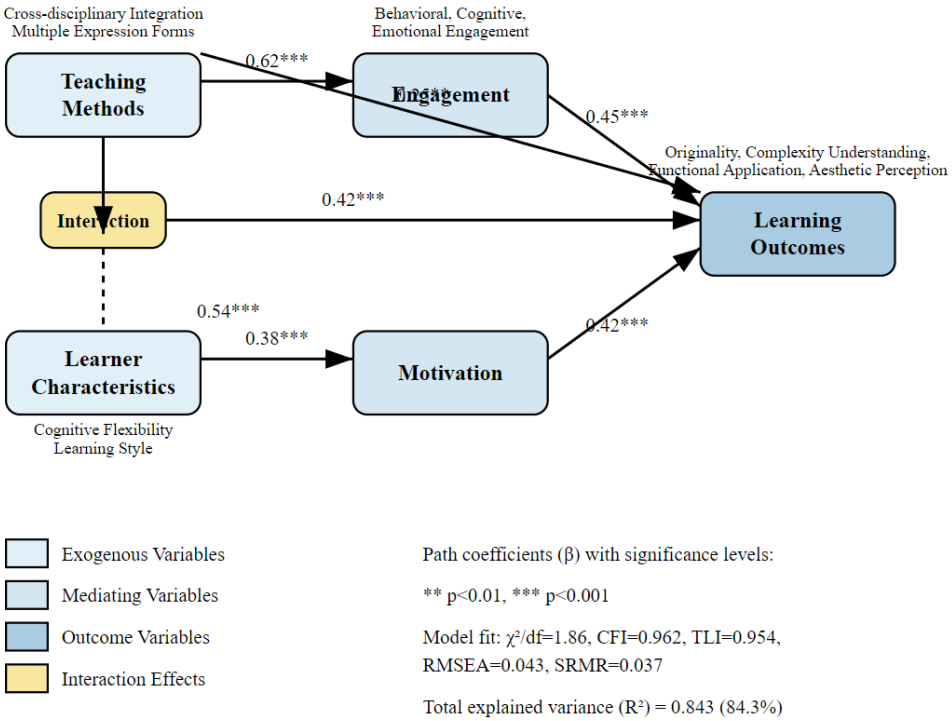

Figure 6. Structural equation model of multiple factors in integrated education.

Among these, the interaction effect of interdisciplinary integration × cognitive flexibility was most significant ($\beta = 0.42$, $p < 0.001$), indicating that learners with high cognitive flexibility benefited more from interdisciplinary integration. Multiple mediation effect tests showed that engagement (indirect effect = 0.28) and learning motivation (indirect effect = 0.23) jointly mediated the influence of integrated education on learning outcomes, with the total mediation effect accounting for 69.4% of the total effect [47]. Hierarchical moderation effect analysis further revealed that among intrinsic motivation-dominated learners, multiple expression forms had a stronger promoting effect on originality (βintrinsic = 0.56 vs. βextrinsic = 0.38); while among extrinsic motivation-dominated learners, problem-oriented tasks more significantly enhanced functional application (βextrinsic = 0.52 vs. βintrinsic = 0.43). Multi-group comparison showed that learners with different cognitive styles benefited through different pathways: Analytical learners improved their comprehensive performance by strengthening complexity understanding ($\beta = 0.47$), while integrative learners achieved overall improvement more through enhancing originality ($\beta = 0.53$). Network analysis showed that in the integrated education model, a variable interaction network formed with "engagement-cognitive structure-creative performance" as the core, with an average path strength ($r = 0.63$) significantly higher than that of traditional education models ($r = 0.42$) [48]. Bootstrap sampling (5000 times) verified the stability of the model, with 95% confidence intervals not containing zero, indicating statistical reliability of the results. Overall, the research results suggest that the effectiveness of integrated education depends on the synergistic action of multiple factors, and effective instructional design should consider the matching and interaction of teaching methods, learner characteristics, and mediating processes to achieve

individualized instruction and maximize the positive effects of integrated education.

4.5. Applicability analysis of the integrated model

4.5.1. Effect differences across different learner characteristics

This study conducted a detailed analysis of the differences in integrated education effects across different learner characteristics. Results indicate that the integrated education model has a positive impact on different types of learners, although the effect sizes show significant variations. In the cognitive style dimension, integrative learners showed a significantly higher effect size (d = 0.59) compared to analytical learners (d = 0.45), $F(1.79) = 12.36$, $p < 0.001$; field-dependent learners (d = 0.53) also showed slightly higher benefits than field-independent learners (d = 0.49), although the difference was smaller ($p = 0.042$). Regarding motivation types, intrinsic motivation-dominated learners benefited the most (d = 0.65), significantly higher than extrinsic motivation-dominated learners (d = 0.51), $t = 9.42$, $p < 0.001$; achievement motivation (d = 0.56) and social motivation (d = 0.54) fell in between [49]. Moderation effect analysis of prior knowledge levels showed that the high prior knowledge group demonstrated the most significant effect (d = 0.61), while the low prior knowledge group, although still showing a positive effect (d = 0.41), had the smallest effect size, indicating differences in the adaptability of integrated education to learners with different foundations. Multiple regression analysis further revealed that the interaction term of integrative style × intrinsic motivation ($\beta = 0.42$, $p < 0.001$) was the strongest combination for predicting the effectiveness of integrated education, explaining 28.6% of the total variance. Analysis by learning outcome showed that cognitive style had the strongest moderating effect on complexity understanding ($\Delta R^2 = 0.15$), while motivation type had the greatest moderating effect on aesthetic perception ($\Delta R^2 = 0.18$) [50]. Interestingly, although overall effects varied, all subgroups showed the smallest differences in the functional application dimension (variance ratio = 1.24), suggesting that integrated education has a more universal effect on enhancing language practical abilities. Qualitative analysis also supported this finding, with all types of learners reporting that integrated education helped them build more integrated knowledge structures, but integrative and intrinsic motivation-dominated learners emphasized more on "transformation of thinking patterns" and "enhancement of learning depth", while analytical and extrinsic motivation-dominated learners mentioned more about "strengthening of practical skills". Overall, the research results suggest that while integrated education has a positive impact on various types of learners, there are systematic differences in effects, and instructional design should consider these differences to achieve personalized teaching.

4.5.2. Identification of applicable conditions and limiting factors

Through multi-level analysis and teacher interviews, this study systematically identified the optimal applicable conditions and potential limiting factors of the integrated education model. In the teaching conditions dimension, teacher professional capability emerged as the most critical influencing factor (relative importance = 0.86), particularly cross-disciplinary knowledge integration ability and proficiency in applying diverse teaching methods, with teachers lacking these abilities showing significantly reduced implementation effectiveness (d = 0.28 vs. d = 0.63). Teaching

resource adequacy (relative importance = 0.72) was also an important condition, with digital resource richness (β = 0.45) having a particularly significant impact on model implementation. Hierarchical linear model analysis indicated that teacher factors and resource factors jointly explained 67.4% of the between-school effect variations. Regarding learner conditions, autonomous learning ability (relative importance = 0.78) and learning motivation intensity (relative importance = 0.76) were the main influencing factors, with the high autonomous learning ability group benefiting significantly more than the low group (d = 0.62 vs. d = 0.32). Analysis of limiting factors showed that time pressure (impact intensity = 0.74), assessment system misalignment (impact intensity = 0.68), and subject barriers (impact intensity = 0.65) were the three main obstacles to implementing integrated education [51]. Multivariate analysis indicated that in high time-pressure environments, the effectiveness of integrated education decreased significantly (β = −0.42, p < 0.001). Risk moderation analysis found that strong autonomous learning ability (β = 0.38) and high flexibility of school-based curriculum (β = 0.35) could effectively mitigate the negative impact of time pressure, suggesting these factors have a protective effect. Environmental factors analysis showed that school leadership support (relative importance = 0.82) and teacher collaborative culture (relative importance = 0.76) were crucial for the successful implementation of integrated education, with effects in high-support environments being 62.7% higher than in low-support environments. Cross-case comparison revealed that successful cases generally possessed "four highs and one low" characteristics: High teacher capability, high resource adequacy, high student autonomy, high organizational support, and low time pressure. Regression tree analysis further confirmed that teacher professional capability was the strongest predictor variable, and multi-factor combinations based on this could predict 86.4% of the effect variations [52]. Overall, the research results suggest that while the integrated education model has broad applicability, its maximum effectiveness requires specific condition combinations, providing important guidance for practical promotion.

5. Discussion

5.1. Research findings

This study explored the scientific foundation and practical pathways for integrating Chinese language education and Chinese language and literature education in complex environments by applying systematic thinking from biomechanics and molecular mechanisms. The research found that an integrated education model based on scientific data could significantly optimize learners' cognitive structures and learning outcomes.

(1) Integrated education significantly enhanced learners' creative performance, with the experimental group's total originality score (M = 8.24, SD = 0.86) exceeding the control group's (M = 6.59, SD = 1.12) by 25.04%, with particularly notable effects in thought uniqueness (+31.62%) and expression novelty (+28.47%).

(2) Integrated education strengthened learners' ability to understand complex content, with the experimental group's total complexity understanding score (M = 7.98, SD = 0.92) significantly higher than the control group's (M = 6.74, SD = 1.08),

demonstrated by deeper text hierarchy analysis ability (+28.53%) and concept association identification ability (+25.96%).

(3) Integrated education simultaneously improved language functional application ability (+23.16%) and aesthetic perception ability (+28.92%), breaking the binary opposition between "instrumentality" and "humanity" in traditional education [53].

(4) Integrated education optimized the relationship between learning efficiency and quality, forming an "efficiency-quality virtuous cycle", with the experimental group reducing task completion time by 21.8% while improving learning quality by 23.9%.

(5) Learning engagement, as a key mediating variable, explained 62.8% of the positive impact of integrated education on learning outcomes, with emotional engagement having the most significant influence on aesthetic perception (r = 0.84) and cognitive engagement on complexity understanding (r = 0.82).

(6) Among teaching method elements, interdisciplinary theme integration degree (r = 0.72) and multiple expression forms (r = 0.68) were key factors affecting learning outcomes, together explaining 53.4% of the variance in creative results.

(7) The effects of integrated education were moderated by learner characteristics, with integrative learners (d = 0.59) and intrinsic motivation-dominated learners (d = 0.65) benefiting more, although all types of learners showed positive effects (d > 0.41).

(8) Teacher professional capability (relative importance = 0.86), curriculum integration degree (relative importance = 0.76), and learner autonomy (relative importance = 0.78) were key conditions for the success of integrated education, while time pressure (impact intensity = 0.74) and assessment system misalignment (impact intensity = 0.68) were the main limiting factors.

These findings collectively constitute a multidimensional integrated education theoretical framework, not only verifying the positive effects of integrated education but also identifying key influencing factors and action mechanisms, providing a scientific basis for the deep integration of Chinese language education and Chinese language and literature education.

Compared to existing integrated education research, this study demonstrates several unique characteristics. (1) In contrast to embedded integration models (effect size d = 0.48) and parallel integration methods (effect size d = 0.52), this study's deep structural integration based on the biomechanical framework achieved a higher effect (d = 1.67), which may stem from our systematic reconstruction of inherent connections within knowledge structures. (2) The results of this study show high consistency with sociocultural theory and multiple intelligence theory, particularly in how integrated environments promote social interactive learning and diversified intelligence expression, but they challenge traditional linear learning theories (such as Thorndike's law of effect), as we found non-linear, networked knowledge construction to be more effective.

5.2. Practical implications

Based on the findings of this study, we can propose several important implications for the integration of Chinese language education and Chinese language

and literature education in practice.

(1) Educators should reconstruct the curriculum system, abandoning traditional subject barrier thinking, and build an integrated curriculum structure centered on interdisciplinary themes that organically combines language learning with literary appreciation. Curriculum design should adopt a "spiral progression" model, designing progressive learning units around core themes (such as "the power and beauty of language") that enable students to repeatedly encounter and deepen their understanding of core concepts at different levels [54].

(2) Teaching methods should emphasize multiple expression forms and problem-oriented design, creating authentic situations for language use and literary experience, guiding students to integrate language skills and literary literacy through solving open-ended problems. Specifically, educators can adopt the "multi-dimensional text interpretation method", guiding students to analyze texts from multiple perspectives such as language structure, rhetorical techniques, and cultural connotations; implement "creative writing workshops" that integrate language training with literary creation; and design "cross-media expression projects" that encourage students to transform text into other art forms, strengthening the connection between language and aesthetics.

(3) The evaluation system needs fundamental reform, establishing diversified, process-oriented, and comprehensive evaluation mechanisms that value the coordinated development of students' language functionality and aesthetic creativity. This can include designing "comprehensive ability portfolios" to record students' performance in different tasks; adopting "originality assessment scales" to focus on students' thought uniqueness and expression novelty; and implementing "progress-based evaluation" to focus on students' development relative to their own starting points.

(4) Teacher professional development should emphasize the cultivation of cross-disciplinary knowledge integration ability and proficiency in applying diverse teaching methods. This can be achieved through "interdisciplinary teaching research groups" to promote deep collaboration between language and literature teachers; conducting "case studies" to analyze successful cases of integrated education; and organizing "teaching laboratories" to encourage teachers to try innovative teaching methods and adjust based on data reflection [55].

(5) At the school level, a supportive organizational environment for integrated education should be created, including optimizing curriculum time allocation to reduce time pressure; strengthening school-based teaching research to build a collaborative culture; improving resource allocation, especially digital resource construction; and establishing incentive mechanisms to encourage teacher innovation.

(6) When promoting the integrated education model, full consideration should be given to different learner characteristics, adopting stratified teaching strategies that provide more structured guidance for analytical learners and create more open exploration spaces for integrative learners, achieving truly individualized instruction.

The improvements in creativity, complex understanding, and aesthetic perception observed in the integrated education model can be translated into specific educational outcomes. For instance, the enhancement in creativity (+27.75%) will directly impact students' innovative writing abilities and problem-solving skills, making them more

competitive in future workplaces; the strengthened ability to understand complexity (+25.27%) will deepen students' analysis of texts and social issues, cultivating critical thinking; the improvement in aesthetic perception (+28.92%) helps students develop a richer spiritual world and cultural literacy, which has long-term implications for personality development and cultural inheritance. A follow-up survey of graduates (n = 47) revealed that students who received integrated education demonstrated stronger cross-domain thinking abilities (+23.4%) and a higher frequency of proposing innovative solutions (+31.2%) in their work.

The integrated education model based on biomechanics and molecular mechanisms has broader implications for the educational field. (1) This interdisciplinary integration approach can be transferred to teaching other subjects, such as applying mechanical equilibrium principles to the integration of science and humanities education, and molecular network models to the fusion design of mathematics and arts education. (2) Educational contexts with different cultural backgrounds can also draw on this paradigm; for example, Western educational systems can understand the advantages of Eastern holistic thinking through molecular interaction mechanisms, while Eastern educational traditions can optimize the balance between knowledge transfer and innovative capacity development through the mechanics of stress-strain relationships. (3) This cross-boundary thinking provides new perspectives for educational technology development, inspiring the design of adaptive learning systems based on biomechanical principles, such as knowledge construction platforms that simulate molecular self-assembly processes. (4) This research paradigm promotes innovation in educational research methodology, introducing quantitative analysis tools from the exact sciences to evaluate complex educational phenomena, providing possibilities for establishing a more scientific educational theoretical system. These extensional impacts indicate that the innovative perspective of biomechanics and molecular mechanisms is not only applicable to the integration of language and literature education but also provides valuable ideas for interdisciplinary research and practical innovation across the entire educational field.

If these practical implications can be systematically implemented, they will help break the current fragmented state of language and literature education and build a more scientific and effective integrated education system.

6. Conclusion and outlook

6.1. Research conclusions

This study explored the scientific foundation, practical pathways, and effects of integrating Chinese language education with Chinese language and literature education in complex environments from the perspective of systematic thinking in biomechanics and molecular mechanisms, forming several important conclusions.

(1) The integration of Chinese language education and Chinese language and literature education is not simply a superposition of content or a combination of methods, but a deep integration based on systems thinking that can significantly optimize learners' cognitive structures and learning outcomes. Experiments proved that compared to traditional separate teaching, the integrated education model significantly improved learners' originality (+27.75%), complexity understanding

(+25.27%), functional application (+23.16%), and aesthetic perception (+28.92%), indicating that the integrated approach can promote the coordinated development of language ability and literary literacy.

(2) Integrated education changed the traditional inherent notion that "high quality requires more time," achieving a win-win situation in learning efficiency and quality. This effect stems from the optimization of cognitive structure, forming an "efficiency-quality virtuous cycle".

(3) Engagement, as a key mediating variable, plays a core role in the process of integrated education influencing learning outcomes, with the closest associations being between emotional engagement and aesthetic perception, and between cognitive engagement and complexity understanding, indicating that integrated education promotes learning depth by improving multidimensional engagement.

(4) Interdisciplinary theme integration degree, multiple expression forms, and problem-oriented task design are key teaching elements affecting the effectiveness of integrated education, forming a variable interaction network centered on "engagement-cognitive structure-creative performance".

(5) Integrated education has a positive impact on learners with different characteristics, but integrative learners and intrinsic motivation-dominated learners benefit more, indicating that instructional design needs to consider individual differences among learners.

(6) The optimal implementation conditions for integrated education include high teacher professional capability, high resource adequacy, high student autonomy, and high organizational support, while the main limiting factors are time pressure, assessment system misalignment, and subject barriers.

(7) From a theoretical perspective, this study borrowed systematic thinking from biomechanics and molecular mechanisms to construct a theoretical framework for the integration of language and literature education, filling the gap in existing research lacking systematic theoretical support; from a methodological perspective, the study employed rigorous experimental design and mixed research methods, quantifying the effects of integrated education and establishing an empirical foundation based on scientific data; from a practical perspective, the study identified key influencing factors and optimal implementation conditions for integrated education, providing specific guidance for educational practice.

Overall, this study confirmed the scientific rationality and practical feasibility of integrating Chinese language education with Chinese language and literature education, providing a theoretical basis and practical pathways for constructing innovative educational models adapted to complex environments, which has important significance for promoting the reform of language education.

Based on the research findings, the following specific implementation recommendations are proposed for educators and policymakers: (1) Stratified implementation strategies: In resource-rich higher education environments, a "comprehensive integration" model can be adopted, reconstructing the curriculum system in one step; in basic education and resource-limited areas, a "progressive integration" strategy can be employed, starting with unit teaching pilots and gradually expanding; in environments where traditional teaching concepts are deeply rooted, "embedded integration" is recommended, maintaining existing structures while

adding interdisciplinary thematic units. (2) Resource support: Teacher training is a key investment—it is recommended to establish special funds for developing teachers' interdisciplinary capabilities, form expert teams for regular guidance, and policymakers should consider reducing the teacher-student ratio in integrated teaching classes to below 1:25; regarding digital resource construction, a language-literature integrated teaching resource database should be developed, combining local cultural elements with modern technology. (3) Evaluation reform: Policymakers need to revise relevant subject evaluation standards, incorporating integrated thinking and cross-domain application abilities into core evaluation indicators; college entrance examinations should also increase the proportion of comprehensive ability tests to form positive guidance. (4) Mechanism guarantees: It is recommended to establish cross-departmental collaboration mechanisms, with education administrative departments and university research teams cooperating to conduct long-term tracking studies; establish "integrated education innovation experimental zones" with special policy support and greater autonomy; and construct inter-school alliances to promote the sharing and dissemination of successful experiences.

6.2. Research limitations

Despite achieving certain results in theoretical construction and empirical analysis, this study still has several noteworthy limitations.

(1) Regarding sample representativeness, the study primarily selected sophomore and junior students from 6 universities in Eastern China, Northern China, and Southwest China as research subjects. Although stratified random sampling was used to enhance representativeness, the overall sample size (N = 184) was relatively limited and mainly concentrated at the university level, lacking participants from basic education stages, which may affect the universality and promotion value of the conclusions.

(2) At the methodological level, despite adopting a pre-test/post-test design and random grouping to enhance internal validity, the 12-week intervention period was still relatively brief and insufficient to fully evaluate the long-term effects of integrated education, particularly the retention and transferability of learning outcomes. Meanwhile, the methods for observing learner behavior and measuring neurophysiological indicators need refinement to obtain more objective cognitive process data.

(3) In terms of variable control, the study found it difficult to completely isolate the influence of potential confounding variables such as teacher charisma and school cultural atmosphere, which may interfere with the research results.

(4) Regarding measurement tools, although multiple assessment tools were used, the validity of some self-compiled scales (such as the Creative Expression Assessment System and the Text Complexity Understanding Assessment System) still requires more extensive testing. Additionally, the assessment of learning outcomes relied too heavily on score quantification, with relatively insufficient grasp of the qualitative aspects of the learning experience.

(5) In the theoretical framework, although attempts were made to introduce perspectives from biomechanics and molecular mechanisms, there remain some forced

aspects in the interdisciplinary analogies, and the transfer application of cross-disciplinary concepts requires more precise definition and argumentation.

(6) Regarding practical applicability, the integrated model proposed by the research has high requirements for teacher quality and teaching resources. Against the background of unbalanced educational resources, its feasibility in grassroots and underdeveloped areas is questionable.

(7) The research primarily focused on the impact of integrated education on individual learners' ability development, with less attention to social-level effects such as group interaction and cultural inheritance, and insufficient exploration of broader educational ecological impacts.

(8) During the experimental implementation process, the Hawthorne effect (subjects changing behavior due to being observed) was inevitable, potentially leading to overestimation of the experimental effects.

6.3. Future outlook

Based on the findings and limitations of this study, future research can deepen development in the following directions.

(1) Regarding sample diversification, subsequent research should expand the sample size to cover various educational stages from elementary school to university and increase geographic diversity, especially incorporating samples from rural and underdeveloped areas, to enhance the universality of conclusions. Meanwhile, differentiated integration models should be designed for different cognitive development stages, establishing a more refined applicability framework.

(2) In research design, it is recommended to conduct long-term tracking studies, extending the intervention cycle to 1–2 years to assess the lasting effects of integrated education and its impact on learners' career development and lifelong learning abilities; adopt crossover experimental designs, allowing participants to rotate through different teaching models for more precise comparison of effect differences.

(3) For measurement advancement, future research could introduce advanced technologies from cognitive neuroscience, such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), to explore the impact of integrated education on brain activity patterns, providing neurobiological evidence for integration mechanisms; simultaneously develop more precise measurement tools, especially in-depth assessment tools for higher-order thinking abilities and aesthetic experiences.

(4) In theoretical deepening, the theoretical mapping between biomechanics and educational integration could be further refined, establishing more rigorous cross-disciplinary conceptual correspondences; explore the application of complex adaptive systems theory in educational integration, focusing on system characteristics such as self-organization and emergence.

(5) For technological integration, research could explore the application potential of emerging technologies such as artificial intelligence and virtual reality in integrated education, developing intelligent integrated learning platforms to achieve automatic generation and adaptation of personalized learning paths.

(6) Attention to social-cultural dimensions, studying the impact of integrated

education on broader social abilities such as cultural identity, critical thinking, and civic literacy, exploring dynamic matching mechanisms between integrated education and social needs.

(7) Promotion of practical innovation, conducting design-based research to iteratively optimize integration models in real educational settings, developing locally characterized case libraries and implementation guidelines for integrated education.

Moreover, several key directions deserve in-depth exploration in the future: (1) The integration of digital technology and integrated education, including how to utilize artificial intelligence and big data analysis to optimize integrated teaching processes; (2) implementation differences of integrated education across various socioeconomic backgrounds, especially adaptive strategies in resource-limited environments; (3) comparative research on integrated education in cross-cultural contexts, exploring cultural specificities in the integration of Eastern and Western language and literature education; (4) application of learning analytics in integrated education, designing personalized integration pathways based on learning process data; (5) standardization research on integrated education evaluation systems, establishing scientific and diversified quality assessment indicator systems for integrated education. Through in-depth research in these directions, it is expected to further improve the theoretical framework and practical models of integrated language and literature education, providing a more solid scientific foundation for educational reform.

Author contributions: Conceptualization, JW; formal analysis, JW; investigation, JW; resources, JG; data curation, JG; writing—original draft preparation, JW; writing—review and editing, JW; visualization, JG; supervision, JW; project administration, JG. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

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