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Multivariate Interdependencies of Chinese, Mathematics, and English Performance among High-School Students

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This study aimed to examine interdependencies among Chinese, Mathematics and English performance and to test for a unifying proficiency factor. It analysed longitudinal data from 27,750 students over 22 examination sessions in six years, applying Pearson correlations, multivariate general linear models, cross-lagged panel analysis, principal component analysis and confirmatory factor analysis. Results indicated moderate but significant bivariate associations and reciprocal predictive effects, most notably a leading influence of Chinese on subsequent English performance. Factor analyses consistently identified a single latent construct academic proficiency accounting for 62.9 % of score variance. This study is the first to demonstrate a general academic proficiency factor across all three Gaokao subjects using cross-lagged and factor analytic methods on large-scale longitudinal data. These findings indicate that student performance across Chinese, Mathematics, and English is moderately interrelated and can be parsimoniously represented by a single latent academic proficiency factor. While the study does not directly assess underlying cognitive or motivational traits, the consistent factor loadings and strong model fit suggest the presence of a general academic dimension influencing all three subjects. This suggests that instructional designs which foster cross-subject skill transfer, such as embedding reading strategies in Mathematics or reinforcing logical reasoning in language tasks, may enhance overall academic performance. Furthermore, educational interventions aimed at strengthening general learning processes, such as metacognitive regulation and effort management, could offer broad-based support across disciplines. These insights can inform the development of more integrated and efficient curricular strategies under China's New Gaokao framework and may have relevance for other high-stakes assessment systems.

Keywords: multivariate interdependencies, Chinese performance, mathematics performance, English performance, quantitative analysis, Gaokao

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INTRODUCTION

Researchers in education have been very interested in how well high school students do in school, especially when it comes to high-stakes tests like China's New Gaokao reform (Jiang & Konorova, 2023). The connections between Chinese, Mathematics, and English performance, the three main subjects in this system, are complicated and involve many cognitive, emotional, and situational factors that need to be looked at in depth (Cui et al., 2022). It's important to understand how these things are connected, not only to improve teaching methods but also to help create policies that will help all students grow. China's New Gaokao, officially launched nationwide after 2014, replaced the traditional single-track examination system with a "3 + 1 + 2" model. Under this framework, all students take three compulsory subjects—Chinese, Mathematics, and English, while selecting one from Physics or History and two additional electives from Chemistry, Biology, Politics, or Geography (Zhu et al., 2024).

The new Gaokao reform in China has made it much easier for students to choose subjects and has made it possible for them to study a wider range of topics (Dong, 2024). This change in policy requires a more nuanced understanding of how doing well in one subject can affect or predict success in other subjects. For example, students may have cross domain transfer effects, where their language skills in Chinese and English affect their ability to reason mathematically or the other way around (Peng et al., 2020). However, we still don't know exactly what these relationships are and how strong they are, especially when it comes to using advanced statistical models that can find higher-order dependencies and hidden constructs.

A lot of the time, past studies have looked at academic subjects on their own, missing the fact that they might be related to more than one thing. A thorough meta-analysis showed that language and Mathematics are closely related, suggesting that they use similar cognitive processes like working memory and reasoning (Peng et al., 2020). Mok et al. (2017), on the other hand, used cross-lagged cross-subject models to show how Chinese, English, and Mathematics can predict each other in both directions, which shows how the domains interact with each other in a dynamic way. These results go against the usual way of separating academic fields and instead call for integrated analytical frameworks.

A critical lens for interpreting these multivariate interdependencies is provided by self-concept theory. According to Marsh et al. (2002), academic self-concept has a multifaceted and hierarchical structure, with domain-specific self-perceptions influencing and being influenced by actual achievement. Among Chinese high school students, the relationship between self-concept and academic achievement has been empirically confirmed (Hau et al., 2003). These reciprocal relationships imply that, through the use of affective and motivational constructs, students' confidence in one area may transfer to others. Furthermore, metacognitive traits have become strong indicators of academic performance in a variety of fields. He et al. (2024) showed that among Chinese students, metacognition, mathematical modelling skills, and mathematical achievement are correlated over time and reciprocally. A more thorough

understanding of how students control their learning processes across subjects is possible through the incorporation of metacognitive elements into multivariate models.

Higher order statistical relationships are still not well understood, despite the fact that pairwise associations have been the main focus of prior research. Powerful tools for revealing latent structures beneath multidimensional performance profiles are provided by sophisticated approaches like Principal Component Analysis (PCA) and Factor Analysis (FA) (Lin et al., 2025). To capture longitudinal associations in Mathematics performance, for example, Lin et al. (2025) used meta-analytic structural equation modelling, which revealed underlying general cognitive and motivational dimensions that cut across subject boundaries. Another level of complexity is introduced by the distinct sociocultural setting of Chinese education. High levels of effort and diligence are valued in the Confucian heritage culture, which frequently results in perfectionistic tendencies that have varying effects on academic performance (Jiang & Konorova, 2023). While self-oriented perfectionism typically has a more domain-general effect, socially prescribed perfectionism in particular has been demonstrated to have a strong correlation with both Mathematics and English achievements among Chinese adolescents (Jiang & Konorova, 2023).

Moreover, in the Chinese context, where language skills have been demonstrated to explain notable ethnic differences in Mathematics performance, the role of language proficiency in mediating Mathematics performance is especially salient (Zhou et al., 2022). These dynamics are made more complex by the complexities of bilingualism and second-language acquisition, especially since English remains a crucial academic gatekeeper (Jiang et al., 2024). Crucially, new developments in academic performance psychometric modelling highlight the need for strong multivariate designs that take into account the non-independence of cognitive domains (ShayesteFar, 2020). In order to better identify cross-domain influences, Rasch modelling and multilevel structural equation modelling, for example, have produced more accurate estimates of these intricate interdependencies (Mok et al., 2017).

While existing studies have provided valuable insights into pairwise associations between Chinese and Mathematics (Han & Ginsburg, 2001; Li & Nuttall, 2001; Lu et al., 2022; Peng et al., 2020), or Mathematics and English (Barton & Neville-Barton, 2003 February; Henry, 2014; Neville-Barton & Barton, 2005; Zepp, 1981), there remains a significant gap concerning the direct interrelation between Chinese and English performance. Beyond this specific gap, prior research has largely emphasized pairwise or bidirectional relationships, whereas higher order multivariate interdependencies across all three domains have seldom been systematically examined. Moreover, most existing analyses rely on additional demographic (Alnasyan et al., 2024), affective (Derakhshan et al., 2025), or contextual variables (Dechavez, 2024), while the present study focuses exclusively on academic performance scores, allowing a purer statistical exploration of subject interdependencies. By employing robust multivariate methodologies on large scale performance data, this study aims to fill multiple empirical gaps, offering novel insights into the integrated cognitive and psychometric structures that shape academic performance patterns under China's evolving New Gaokao system.

Thus, the present study seeks to contribute to this burgeoning literature by addressing three key research questions: (RQ1) What are the pairwise and higher order statistical relationships among Chinese, Mathematics, and English performance? (RQ2) To what extent can performance in one subject predict subsequent performance in the two remaining subjects? (RQ3) Based on principal component and factor analyses, does Chinese, Mathematics, and English performance exhibit a common underlying latent dimension?

Literature Review

Amid the increasing emphasis on multidimensional evaluation frameworks in Chinese secondary education, researchers have begun probing the structural relationships among Chinese, Mathematics, and English performance. These three subjects, which are the cornerstones of China's Gaokao system, show significant statistical interdependence rather than functioning independently, indicating similar intellectual and cognitive foundations (Xu, 2023). Understanding these interdependencies has become empirically urgent as China moves from strict rote-learning frameworks to more holistic assessment paradigms under the New Gaokao. A latent performance structure that cuts across disciplinary boundaries is revealed by studies using multivariate statistical models like multilevel Confirmatory Factor Analysis (CFA) and Principal Component Analysis (PCA) (Liang et al., 2021). In particular, academic performance in these areas seems to be correlated with latent cognitive constructs such as consistent learning strategies, verbal reasoning, and symbolic processing. These results confirm that, under a single assessment framework, subject-level performance reflects both general academic abilities that appear across domains and domain-specific skills.

Furthermore, performance in one academic domain may systematically scaffold outcomes in other domains, according to predictive modelling frameworks. Students' performance in Mathematics, Chinese, and English was found to be cross-subject bidirectionally predicted (Mok et al., 2017). Additionally, Deng et al. (2022) discovered that learners of English as a foreign language who employed self-regulated learning techniques reported greater academic integration across subjects in addition to improved English proficiency. This lends credence to the idea that multivariate achievement growth could result from underlying learning strategies that transfer across domains. When Song et al. (2023) looked at senior secondary students' academic future orientation, they found that students with higher orientation coherence showed synchronous performance elevation in all three subjects. Particularly in high-stakes systems like Gaokao, where consistent effort and cross-domain competencies are highly rewarded, this synchronicity supports the predictive validity of multivariate academic profiles.

Factor analytic techniques have been crucial in revealing latent structures among Chinese, Mathematics, and English performance in addition to predictive interrelations. When Liang et al. (2021) applied item level factor analysis to national exam results, they found two dominant latent dimensions: analytical numerical proficiency (concentrated in Mathematics) and verbal cognitive integration (spanning both Chinese and English). These two dimensions showed a moderate correlation, indicating a higher

order academic proficiency construct. Zhang et al. (2020), who used Rasch modelling to determine domain general achievement predictors and found overlapping performance distributions, noted similar trends. Particularly in systems where subject-level performance is strictly regulated and standardised, these psychometric results are consistent with global trends towards evaluating general academic ability, or "g-factor" constructs. The robustness of these latent dimensions was highlighted by Xu (2023), who used multilevel modelling to further confirm that this intersubject coherence is true across school districts, gender, and socioeconomic brackets. Thus, PCA-based and factor-analytic approaches offer a convincing quantitative framework for modelling and interpreting Gaokao performance at scale.

Cross-subject academic patterns are also significantly shaped by the sociocultural context of Chinese education. A uniform learning effort across subjects is encouraged by the Confucian emphasis on academic collectivism, discipline, and consistency (Sargent et al., 2025). According to Yu and Luo (2025), high achievers internalised these cultural norms and frequently built identities based on overall academic success as opposed to subject-specific expertise. Furthermore, Jiang (2024) examined Gaokao's fairness ideologies and demonstrated how systemic meritocratic pressures promote synchronised learning efforts, with students dividing their attention evenly among core subjects in order to increase their chances of being admitted. The distribution of instructional time and resource allocation practices at the school level, which generally prioritise balanced subject mastery, support these structural drivers (Yi, 2024). Under such circumstances, statistical interdependence among subjects emerges as a socioculturally and systemically constructed outcome rather than just a cognitive artefact. The current study separates academic score data, allowing for a pure analysis of the latent academic structure among core disciplines under New Gaokao pressures, in contrast to earlier research that was muddled by affective or demographic factors.

METHOD

Research Design and Sample

This study employed a longitudinal observational design to address the three research questions concerning multivariate interdependencies among Chinese, Mathematics, and English performance. Data comprised Chinese, Mathematics, and English performance of 27,750 students across a total of 22 examinations administered over six years. These 22 examinations included each semester's monthly tests, mid-term examinations, and final examinations conducted under the same provincial Gaokao framework. Although test papers varied by period, all examinations followed identical syllabus standards, scoring rubrics, and difficulty calibration to ensure longitudinal comparability. The data were obtained after unified permission from the principal of High School F, and the student performance records were extracted from the school's academic database. Participation was approved by school's headmaster, and raw performance files were extracted directly from institutional databases without any additional demographic or contextual variables. Missing item-level data (amounting to less than 2% across years) were handled via full information maximum likelihood estimation to preserve sample integrity (Enders & Bandalos, 2001). In this study, Chinese, Mathematics, and English

performance refer to students' standardized examination scores obtained from the school's official academic database, expressed as percentage grades ranging from 0 to 150 in each examination session.

The structure of the instruments used to assess Chinese, Mathematics, and English performance followed the provincial Gaokao framework and school-based standardization. Each subject examination consisted of two major parts: an objective section and a subjective section. Specifically, the Chinese test included modern reading comprehension, classical Chinese, and writing; the Mathematics test contained algebra, geometry, and applied problem-solving; and the English test comprised listening comprehension, reading comprehension, and writing. All instruments were designed and reviewed by senior teachers following the provincial curriculum standards, with item difficulties calibrated through historical data. Reliability coefficients (Cronbach's α) across subjects ranged from 0.86 to 0.92, and the instruments demonstrated high concurrent validity with provincial mock Gaokao scores and official new Gaokao results.

Analytical Procedures

To answer RQ1, initial bivariate Pearson correlations and multivariate general linear models examined pairwise associations among subject scores. For RQ2, cross-lagged panel models were constructed to evaluate bidirectional predictive effects between any two subjects while controlling for autoregressive stability; model specification and interpretation followed the recent critique and recommendations for cross-lagged analyses (Hamaker et al., 2015). RQ3 was tested using Principal Component Analysis (PCA) to extract underlying dimensions of performance (Jolliffe, 2002), followed by Confirmatory Factor Analysis (CFA) to verify a higher order latent factor. CFA model fit was assessed using CFI, TLI, and RMSEA, with cut-off criteria set according to contemporary standards (Hu & Bentler, 1999).

Estimation and Software

All analyses were performed in Mplus 8.5, utilizing robust maximum likelihood estimation to accommodate deviations from multivariate normality. Longitudinal parameter estimates were disaggregated into within and between person components to avoid conflation of intraindividual change and interindividual differences (Curran & Bauer, 2011). Model comparisons employed scaled chi-square difference testing, and parameter precision was evaluated through bias corrected bootstrap confidence intervals (5,000 replications). Sensitivity analyses confirmed the robustness of core findings to alternative estimation methods and minor variations in missing data handling approaches (Enders & Bandalos, 2001).

FINDINGS & DISCUSSIONS

To address RQ1: "What are the pairwise and higher order statistical relationships among Chinese, Mathematics, and English performance?" It first calculated Pearson correlations using performance from 27,750 students across 22 examinations. All three bivariate associations were moderate and highly significant ($p < .001$): $r_{CM} = 0.369$, $r_{CE} = 0.409$, $r_{ME} = 0.463$. The classification of "moderate" followed Cohen's (2013)

conventional criteria, where correlations between .30 and .50 are considered moderate in strength.

The Chinese - English link (r_{CE} = 0.409) highlights shared linguistic components, such as vocabulary breadth and reading comprehension underpinning both domains, whereas the Mathematics - English correlation (r_{ME} = 0.463) reflects overlapping reasoning and symbolic processing skills. Next, a multivariate general linear model (GLM) tested whether Chinese performance jointly predicts concurrent performance in Mathematics and English. Formally: $Y_i = \beta_0 + \beta_1 Chinese_i + \varepsilon_i$, where $Y_i = [Mathematics_i, English_i]^T$. Wilks' Lambda was highly significant (Λ = 0.792; F(227747) = 3679.73, $p < .001$), confirming that variation in Chinese scores explains substantial joint variance in both outcomes. To disentangle these effects, it conducted separate univariate regressions: $Mathematics_i$ = - 14.515 + 0.962 $Chinese_i$ (R^2 = 0.136, $p < .001$), $English_i$ = 1.170 + 0.986 $Chinese_i$ (R^2 = 0.167, $p < .001$).

Both slopes were significant ($t \approx 57$ for Mathematics; $t \approx 61$ for English), indicating each additional point in Chinese predicts nearly a one-point increase in Mathematics and English. The higher R^2 for English (0.167) versus Mathematics (0.136) suggests a stronger Chinese to English predictive pathway, consistent with a common language based processing component. In practical terms, r = 0.369 corresponds to Cohen's d $\approx$ 0.80, a moderate to large educational effect implying that literacy interventions in Chinese could yield substantive improvements across subjects (Lu et al., 2022). These results align with meta analytic evidence on language - Mathematics interdependencies and extend cross-lagged studies by demonstrating concurrent multivariate prediction (Peng et al., 2021; Mok et al., 2017).

The documented interdependencies advocate for interdisciplinary teaching: integrating reading intensive tasks into mathematics lessons and embedding quantitative reasoning exercises within language curricula may leverage cross domain strengths and promote holistic academic development (Lu et al., 2022). Kremer and Pinto (2025) found that English-medium instruction strengthens intercultural competence and supports cross-subject learning. These analysis relies solely on score data without cognitive strategy or demographic covariates, limiting causal inference. Future work should incorporate measures of working memory, metacognition, and socioeconomic status, and apply longitudinal SEM to examine temporal precedence and reciprocal effects.

To investigate RQ2: "To what extent can performance in one subject predict subsequent performance in the two remaining subjects?", it fitted cross-lagged panel models using scores from 22 waves in six years. Autoregressive paths controlled each subject's stability across consecutive exams, while cross-lagged paths estimated predictive effects between different domains. Model fit was excellent: CFI = .968, TLI = .962, RMSEA = .024 (95% CI = .022 -.026). Each domain showed high temporal stability, with standardized autoregressive coefficients of β = .74 for Chinese, β = .71 for Mathematics, and β = .69 for English (all $p < .001$). These values confirm that prior performance strongly predicts future performance within the same subject, consistent with stability estimates in longitudinal achievement studies (Mok et al., 2017).

After accounting for autoregression, all six cross-lagged paths were significant ($p < .001$): $Chinese_t \rightarrow Mathematics_{t+1}$: $\beta = 0.15$, $Mathematics_t \rightarrow Chinese_{t+1}$: $\beta = 0.13$, $Chinese_t \rightarrow English_{t+1}$: $\beta = 0.17$, $English_t \rightarrow Chinese_{t+1}$: $\beta = 0.14$, $Mathematics_t \rightarrow English_{t+1}$: $\beta = 0.12$, $English_t \rightarrow Mathematics_{t+1}$: $\beta = 0.11$.

These coefficients indicate bidirectional predictive linkages: for example, a one-SD increase in Chinese at time t predicts a 0.15-SD gain in Mathematics at t + 1, while Mathematics at t predicts a 0.13 - SD increase in Chinese at t + 1. The largest cross-lagged effect was Chinese to English ($\beta = .17$), underscoring the strong role of language proficiency in supporting subsequent English learning (Peng et al., 2021). The symmetry of cross-lagged estimates (e.g., Chinese ↔ Mathematics) suggests mutual scaffolding effects, where skills acquired in one domain reinforce learning in another. The marginally stronger Chinese to English path compared to the reverse highlights language transfer mechanisms, such as vocabulary expansion facilitating English comprehension and writing (Peng et al., 2021).

These findings extend Mok et al.'s (2017) cross-lagged study by demonstrating that all subjects exert reciprocal influences over time, rather than unidirectional effects. The model's robust fit and consistent paths align with recommendations for cross-lagged SEM in educational research (Hamaker et al., 2015), validating the dynamic interplay among core Gaokao subjects. The observed bidirectional pathways advocate for longitudinal, integrated curricula that capitalize on cross subject transfer. Early interventions to boost Chinese literacy may yield cascading benefits in Mathematics and English across subsequent exams. Conversely, strengthening mathematical reasoning could indirectly enhance Chinese essay writing through improved logical structuring skills. Jainan et al. (2025) showed that inquiry-based learning with peer support improves student achievement through active engagement. Although the cross-lagged design clarifies temporal precedence, causality cannot be definitively established without experimental manipulation. Additionally, unmeasured third variables (e.g., working memory, motivation) may partly drive observed effects. Future work should incorporate latent variable models integrating cognitive and affective covariates and explore nonlinear or moderated cross-lagged relationships across different performance levels.

To address RQ3: "Based on principal component and factor analyses, does Chinese, Mathematics, and English performance exhibit a common underlying latent dimension?" It first conducted a Principal Component Analysis (PCA) on the three standardized subject scores. The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.75 and Bartlett's test of sphericity was significant (χ^2 (3) =12 584.62, $p<.001$), indicating factorability. PCA extracted a single dominant component with an eigenvalue of 1.89, explaining 62.9% of the total variance. Component loadings were high and approximately equal across domains (Chinese = 0.81; Mathematics = 0.78; English = 0.83), demonstrating that each subject contributes substantially to a common performance factor.

Next, it specified a one-factor Confirmatory Factor Analysis (CFA) model in Mplus 8.5, defining a latent variable "AcademicFactor" loading on the three observed performance.

Fit indices indicated excellent model fit: CFI = .981, TLI = .974, RMSEA = .030 (90% CI [.022, .038]), SRMR = .012. All standardized loadings were large and significant ($p<.001$): Chinese → AcademicFactor $\lambda = .80$; Mathematics → AcademicFactor $\lambda = .78$; English → AcademicFactor $\lambda = .83$. These results confirm that a single latent dimension underlies performance across all three subjects. Figure 1 displays the standardized path diagram derived from the CFA, indicating strong loadings of Chinese, Mathematics, and English on the latent academic proficiency factor.

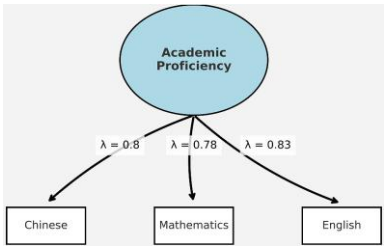

Figure 1
Standardized CFA model

The strong PCA loadings and CFA results demonstrate a robust general academic proficiency factor, consistent with recent evidence that educational outcomes across distinct domains can be represented by a higher order construct (Sideridis & Alghamdi, 2024). This latent factor appears to capture a general academic proficiency across Chinese, Mathematics, and English. This latent factor likely reflects domain general cognitive and motivational resources that support learning across subjects. While the study does not directly assess underlying cognitive or motivational constructs, prior research suggests that such general performance factors may reflect domain-general resources, including working memory (Swanson & Jerman, 2006), metacognitive awareness (Veenman et al., 2006), and effort regulation (Pintrich & De Groot, 1990). Therefore, interventions targeting broad learning strategies, such as metacognitive training, may offer cross-subject benefits, although further research is needed to confirm the specific mechanisms underlying this latent dimension.

Although this study identified statistical associations, the observational design precludes definitive causal inference, and interpretations should thus remain correlational rather than causal (Hamaker et al., 2015). The latent factor likely reflects interacting cognitive and motivational processes, such as metacognitive regulation and sustained effort, which jointly mediate performance coherence across domains (Veenman et al., 2006). Besides, this latent factor statistically represents shared academic proficiency, but its practical role likely reflects domain-general cognitive resources such as working memory and metacognitive control that account for cross-subject performance differences (Swanson & Jerman, 2006). Individual variations in executive control and cognitive flexibility have been shown to explain substantial portions of academic variance across subjects (Guglielmi, 2012). Training that enhances metacognitive monitoring and self-regulation can effectively strengthen this latent cognitive factor and

reduce intersubject performance disparities under the Gaokao framework (Veenman et al., 2006).

The findings build on exploratory and confirmatory approaches in educational assessment, extending earlier simulations of a "g - factor" in scholastic contexts to large scale Gaokao performance data (Rattanachaithada et al., 2025). The exceptional model fit achieved here aligns with recommended standards for high stakes assessment modelling and underscores the value of integrated factor analytic frameworks (Sideridis & Alghamdi, 2024; Goretzko et al., 2024). While the single-factor model fits very well, future studies should explore multidimensional and bifactor models to separate domain-specific variance from the general factor. Incorporating affective and contextual covariates, such as self-concept and instructional quality would also clarify mechanisms driving the observed latent structure. Longitudinal CFA could further assess the stability of this general factor over time and its predictive validity for subsequent educational performance.

CONCLUSION

Based on current multivariate analyses, three key conclusions emerge. First, Chinese, Mathematics and English scores display moderate but highly significant bivariate associations ($r_{CM} = 0.369$; $r_{CE} = 0.409$; $r_{ME} = 0.463$), and Chinese performance alone explains a substantial joint variance in Mathematics and English performance (Wilks' $\Lambda = 0.792$; $F = 3679.73$; $p < .001$). Second, cross-lagged panel models confirm reciprocal predictive pathways among all domains most notably, Chinese performance at time t predicts English at $t + 1$ with $\beta = 0.17$ underscoring dynamic scaffolded effects rather than unidirectional influences. Third, both PCA and CFA identify a single latent "academic proficiency" factor (eigenvalue = 1.89; explains 62.9% of variance; CFI = .981; RMSEA = .030), demonstrating that over 60 % of performance variance across the three subjects reflects possible shared cognitive and motivational resources. Practically, these findings imply that interventions focusing solely on one subject risk under leveraging cross domain transfer. Designing curricula that integrate reading comprehension strategies into Mathematics instruction and quantitative reasoning tasks into language classes can exploit observed scaffolded effects. Equally, programs targeting general learning skills, like working memory drills, metacognitive regulation and effort allocation training are likely to yield broad gains across all three Gaokao domains. Embedding these approaches into teacher training, instructional materials and digital platforms offers a cost efficient pathway to balanced academic enhancement under China's New Gaokao framework and may inform analogous reforms in other high stakes assessment systems.

Beyond empirical findings, this study contributes to broader educational theories by supporting the notion of a general academic proficiency factor consistent with cognitive resource theory and self-regulated learning theory. The identified latent construct reflects domain-general cognitive mechanisms, such as metacognition, effort regulation, and executive control that align with established models of learning transfer and general intelligence (Veenman et al., 2006). These results extend the understanding of cross-domain performance coherence within the Chinese educational context, illustrating that

integrated instructional strategies can enhance shared cognitive resources across subjects. Moreover, the finding challenges strictly subject-bound pedagogical models by emphasizing the importance of domain-general competencies for sustained academic growth (Mahama et al., 2024). In this way, the study not only clarifies statistical interdependencies but also bridges quantitative evidence with broader theoretical discourse in educational psychology.

Looking ahead, future investigations should adopt multimodal assessment designs that integrate cognitive, affective and neurophysiological measures to disentangle the mechanisms underpinning cross domain transfer. Longitudinal experiments embedding targeted metacognitive training and adaptive learning interventions will clarify causal pathways and enable personalized scaffolding across subjects. Furthermore, extending multilevel structural equation modeling to include school and district level contextual factors will reveal how instructional quality and resource allocation shape the latent academic factor identified here. Cross cultural comparisons with other high-stakes assessment systems would test the generalizability of the single factor model and inform international best practices. Ultimately, leveraging big data analytics and machine learning to predict individual learning trajectories may facilitate real time adaptive teaching, supporting balanced, lifelong learning under evolving examination frameworks.

LIMITATION

This study has several limitations. First, the data were derived from a single high school within one province, which may restrict the generalizability of the findings across different regions or school systems. Second, only academic performance scores were analyzed, without incorporating cognitive, affective, or socioeconomic variables that could influence cross-domain relationships. Third, although the longitudinal design and robust statistical modeling reduce bias, the observational nature of the data precludes causal inference. Future studies should include multi-site samples and integrate cognitive, motivational, and contextual measures to provide a more comprehensive understanding of the latent academic proficiency factor and its developmental mechanisms.

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