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The changes of creativity among Chinese primary and middle school students (2007-2022)

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Article

Keywords: Creativity, Innovative Talents, Basic Education, Cross-temporal Meta-analysis

Posted Date: February 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-6533138/v1

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Additional Declarations: No competing interests reported.

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[Abstract] Global development, when considered in the contemporary international competitive practices, demonstrate that talents represent the key strategic resource. Innovation as well as the core driving force for development. The youth population also crucial motivates the global technological revolution and cross-border collaborative innovation due to their open-mindedness and vitality in cross-border activities. Therefore, it is necessary to explore creativity change trends among primary and secondary school students. Accordingly, this study collected data consisting of data covering 16 years in total with respect to creativity tendencies among Chinese primary and secondary school students. Employing a cross-sectional historical meta-analysis, this finding indicates a continuous increase over the years in the creativity of these students. Their adventurousness, curiosity, imagination, and challenge power factors also exhibit constant positive trends. Further analysis explored the predictive effect of social indicators on creativity. The exploration determined that national education funding, educational funding per student, the availability of full-time teachers and those holding senior titles, and the number of school-based digital terminals exhibit significant or marginal predictive power regarding students' creativity and its components. When comparing students across the three educational stages (primary, junior high, senior high), high school students exhibited the largest growth in overall creativity and challenge power. Primary school students, in comparison, demonstrated the greatest increases concerning adventurousness, curiosity, and imagination factors. A comparison between male and female students indicated no significant overall difference; however, male students displayed a more significant increase in both creativity and its related factors. Innovative talent cultivation hinges upon nurturing student creativity and cultivating the development of factors such as adventurousness, curiosity, imagination, and challenge power. Both augmenting the supply of educational resources and respecting the individual developmental paths of students contribute positively, to a certain degree, toward achieving this objective.

[Keywords] Creativity; Innovative Talents; Basic Education; Cross-temporal Meta-analysis

Introduction

Creativity, also referred to as innovative ability, signifies a unique human characteristic (Lin,1999;Lubar and Sternber ,1996;Williams,1967) . It is from the most fundamental qualities of talent and functions as an intellectual quality that utilizes all available information to fulfill a purpose, resulting in a novel and unique product with social and personal value. In the current era defined by globalization and the swift expansion of the knowledge economy, creativity has risen to become a critical element for cultivating social advancement and ensuring individual success. For individuals, creativity enhances the capacity to solve complex problems and facilitates adaptation to the evolution of a diverse society (Tao et al.,2023);for countries, it offers an inexhaustible source of momentum for development and ethnic progress (Hu et al.,2024). Discovering how to more effectively cultivate student creativity represents a core reform challenge confronting education systems worldwide. China itself is experiencing a crucial

phase involving an accelerated transition from relying on a demographic dividend to leveraging a talent dividend for high-quality growth, placing great emphasis on developing innovative talents. For instance, General Secretary Xi Jinping proposed in the 20th National Congress of the Communist Party of China report in 2023 that innovation stands as the foremost driving force, urging efforts to cultivate premier innovative talents(Xi,2022).New quality productivity was newly included in the government work report during the 2024 Chinese People's Congress and Chinese People's Political Consultative Conference sessions, positioning innovation as its central component(Ministry of Education of the People's Republic of China,2024).Educational institutions represent the principal environments for cultivating innovative talents(Chen et al.,2023). Cultivating students' innovative capabilities is their primary goal, which thus lays a solid groundwork during the primary and secondary school years for nurturing the innovative talents needed by new quality industries(Zhu et al.,2024;Dong et al.,2024).Thus, the methodology for cultivating creativity among primary and secondary school students commands widespread interest among a number of researchers. Existing studies, however, have mostly adopted a cross-sectional approach. Such research typically involves surveys conducted only during a limited period, hindering the observation of how student creativity evolves over many years or alongside social development. Previous analyses have also primarily discussed creativity's influencing factors through the perspective of specific teaching practices, rather than considering whether creativity changes might also be affected by macroscopic social factors. This study, therefore, utilizes the cross-sectional historical meta-analysis method. The aim is to explore comprehensively and objectively how the creativity of students in Mainland China has changed over time and to study the ways social macro factors impact these changes based on collected data.

The Raising of the Research Questions

1. The Changes in Creativity of Chinese Primary and Secondary School Students

China's basic education system continually emphasizes the cultivation of student creativity from both conceptual and practical standpoints. This focus arises from the strategic necessities of constructing an education powerhouse, establishing a world-class talent center, and developing an innovation highland, while also considering the natural laws governing talent growth and educational progress.

Firstly, the objectives guiding curriculum reform demonstrate significant shifts over time. Since the establishment of the People's Republic of China, basic education curriculum reform has evolved; its initial focus on the "dual bases" transitioned first to "three-dimensional objectives" and following "core literacies." The Ministry of Education introduced the "Provisional Regulations for Middle Schools (Draft)" in 1952(Ministry of Education of the People's Republic of China,2009;Wang,2016).This document represented the first explicit proposal of the "dual bases," which aimed to facilitate students in obtaining foundational knowledge and skills in modern science. This acquisition was regarded as a necessary pathway for learning more advanced knowledge. The "dual bases" framework successfully promoted teaching efficiency, enhanced national quality, and yielded remarkable achievements. However, China's overall basic education level was low at the time, and the "dual bases" became associated with negative practices such as "exam-oriented education," "cramming" teaching styles, and "rote learning," largely driven by an excessive focus on enrollment rates(Zhang,2018).Thus, this approach struggled to fulfill the mission of comprehensive student development. It instead severely weakened students' innovative spirit and abilities(Liu,2010).The traditional basic

education curriculum centered on the "dual bases" thus became inadequate for meeting contemporary needs. Recognizing this, the Central Committee of the Communist Party of China, the State Council, and the Ministry of Education initiated significant reforms. They decided to vigorously advance basic education curriculum reform and construct a new system aligned with quality education requirements. The "Outline of Basic Education Curriculum Reform (Trial)" released in 2001 explicitly introduced the "three-dimensional objectives" for the first time, including knowledge and skills, processes and methods, and emotional attitudes and values(Ministry of Education of the People's Republic of China,2001).Certain studies suggest that these "three-dimensional objectives" surpassed the traditional "dual bases theory" by reflecting the inherent value of modern disciplines(Zhong,2010). This approach was viewed as a corrective measure to reduce the effects of "exam-oriented education"(Zhong,2010) .Compared to the "dual bases," it placed greater emphasis on liberating student creativity during the knowledge acquisition process, thereby enabling students to reach a state where they could solve problems creatively(Liu,2009).Nevertheless, certain scholars expressed dissenting views. They argued that while the "three-dimensional objectives" did highlight student initiative beyond the "dual bases," their framework suffered from a chaotic structure (Wang,2016)and a lack of overall integrity(Yu,2016).These weaknesses led to teacher misunderstandings and practical alienation, rendering it a challenging task for educators to integrate objectives from the different dimensions. Therefore, the intended meaning of the "three-dimensional objectives" became fragmented(Yan and Yang,2021).This fragmentation finally created a gap between China's stated value proposition for cultivating student creativity and the practical utility of the curriculum objectives. Addressing the shortcomings of the "three-dimensional objectives," the Ministry of Education issued the "Opinions of the Ministry of Education on Fully Deepening Curriculum Reform and Implementing the Fundamental Task of Moral Education" in 2014. This document stipulated that "core literacies" should guide education, focusing on developing students' innovative spirit and exploratory abilities(Ministry of Education of the People's Republic of China,2014).Further reinforcement came in 2022 with the "Compulsory Education Curriculum Plan and Standards (2022 Edition)," also issued by the Ministry of Education. This plan highlighted the need to fully implement a cultivation concept centered on core literacies, concentrating on nurturing patriotism, practical ability, and innovative spirit among students(Ministry of Education of the People's Republic of China,2022)."Core literacies" differ from both the "dual bases" and "three-dimensional objectives" by stressing the integration of knowledge and action and the combination of learning and thinking. This latest approach advocates for methods such as "learning by doing," "learning by using," and "learning by innovation," aiming to inspire students' innovative spirit through practical application(Liu and Li,2023). Simultaneously, core literacies offer more comprehensive and in-depth support for creativity development, better equipping innovative talents to face future challenges.

Secondly, the content targeted for cultivation has broadened from isolated knowledge points to an interconnected knowledge matrix. Initially, cultivation content was restricted to understanding and analyzing specific items such as facts, principles, rules, and concepts. The foundational knowledge derived from such indirect experiences can establish a solid base for acquiring higher-order literacies, including innovation, critical thinking, and problem-solving skills(Chu,2021). However, this static perspective on knowledge neglects its developmental importance for individual student creativity(Guo,2021).Educational content should consist of not only static, indirect experiences but also students' direct experiences in real-life situations(Shi,1996;Zhong,2007).Therefore, the focus of educational content needed to shift. Instead of concentrating solely on subject knowledge, emphasis should be placed on the

significance of knowledge for cultivating core literacies(Shi,2016).This involves selecting subject matter containing the most valuable core literacy components from the vast pool of knowledge. It also involves organizing this selected content structurally, transitioning from discrete knowledge points towards a cohesive knowledge matrix(Yu and Long,2022). From the perspective of individual subjects, learning content is structured and integrated across three dimensions: knowledge itself, social life connections, and learner orientation. This structure assists students in gradually internalizing literacies as they acquire and experience knowledge, stimulating creativity while addressing personalized needs(Liu,2020).Considering knowledge itself, this approach organically integrates content from related subjects. It arranges teaching material logically by considering both the evolution of knowledge and students' physiological development, forming interdisciplinary concept maps. Learners are encouraged to employ creative thinking through this structure, finally enhancing their creative thinking processes and significantly boosting their creative abilities(Chen and Zhang,2010).

Thirdly, teaching methodology demonstrates a gradual transition from "teacher's teaching" towards "student's learning"(Peng and Peng,2023).Traditional teacher-led processes often exhibited a pattern where "students listen to what teachers talk, copy what teachers write and memorize what teachers test."(Kang et al.,2003)This form of "knowledge instructionism" excessively emphasized the teacher's leading role and represented a typical "cramming" method. Its focus remained primarily on knowledge transmission and exam preparation, neglecting the student's role as the central agent in learning, which stifled learning creativity(Liu,2015).As studies progressed, "teacher-centered" teaching began shifting towards "student-centered" approaches. This shift allows students to discover and create knowledge independently while respecting their interests and needs(Liu,2012).Teachers in this updated paradigm are no longer mere imparters of knowledge; instead, they function as creators of learning environments. They encourage active student participation, cultivate independent exploration and collaborative learning, stimulate students' interest, and thereby develop their creativity. Creative teaching methods and concepts, therefore, offer a more effective means of promoting the development of student creativity(Esquivel,1995).

Finally, student evaluation practices are evolving from a narrow, grade-based assessment to a comprehensive, process-oriented evaluation that highlights the educational value of assessment itself. Exploring evaluation content and methods, traditional evaluation was heavily influenced by the historical concept of "excellence in learning leads to officialdom." This perspective demanded that students acquire vast amounts of knowledge, utilizing grades as the primary measure of talent(Zhang et al.,2015). It heavily relied on summative evaluation, which often caused students to lose enthusiasm for learning, negatively affected their holistic development, and suppressed their creativity. In China's initiative to "Eliminate the Over-Reliance on Five Elements," evaluation content has broadened considerably. It now includes dimensions such as ability, attitude, and reflection, extending beyond mere knowledge and skills. The focus is increasingly on assessing students' capacity to flexibly apply knowledge and experience for creative problem-solving. In addition, multiple evaluations are now conducted throughout the cultivation process—at early, middle, and later stages. This creates a dynamic profile through whole-process evaluation(Wang and Fan,2022;Wang et al.,2014),which promotes the development of students' comprehensive application abilities and cultivates their critical and innovative thinking. Regarding the evaluation subject, teachers historically held absolute authority in the evaluation system. This positioning rendered students passive recipients, leading them to gradually lose reflective capacity and lack recognition of their own diversity, thereby limiting creativity development(Wei and Lin,2023).Current practices emphasize

integrating students into the evaluation sphere. This cultivates an evaluation "community" involving teachers, students interacting with teachers, and students evaluating peers. Diverse self-evaluation and peer evaluation methods are employed, combining rich evaluation content and forms to offer students space for self-reflection, thus stimulating their creativity(Wei and Lin,2023).

According to these observations, it is evident that the cultivation of creativity is progressively advancing towards modernization and scientific rigor. Nevertheless, identifying the specific changing trend of student creativity from existing studies remains challenging. This study utilizes a cross-sectional historical meta-analysis method. Its purpose is to explore the changing trend of creativity changes among Chinese primary and secondary school students alongside societal development and ongoing educational reforms.

2.Factors Affecting the Changing Trend of Creativity among Chinese Primary and Secondary School Students

Lin Chongde conceptualizes that "innovative talents = creative thinking (intellectual factors) + creative personality (non-intellectual factors)"(Ma and Zhai,2003).His definition indicates the significance of intellectual factors for cultivating innovative talents; however, it also highlights the indispensable role of developing non-intellectual factors. Analyses into non-intellectual factors impacting creativity among primary and secondary students often analyze demographic variables. Discussions most extensively cover education stages and gender, but researchers report inconsistent results. Contradictory findings exist regarding education stages. Certain scholars propose that student creativity develops through a step-by-step process(Fu et al.,210).Others assert that high school freshmen generally exhibit higher creativity than sophomores and middle school students(Lin,2010); whereas, different research has identified no significant difference in creativity across various age groups(Chen and Wang,2010). Similar inconsistencies appear in gender-related findings. While some researchers report higher creativity in girls compared to boys(Wang et al.,2005), alternative studies reach the opposite conclusion, suggesting boys exhibit greater creativity(Wo et al.,2009).Nevertheless, other research indicates that creativity levels are nearly identical for boys and girls in primary school; however, boys demonstrate significantly higher creativity during middle school(Guo etal.,2018).Two potential explanations may account for these discrepancies in research results. Differences in demographic variables, such as the specific times and populations evaluated in the studies, could be one reason. The use of varied questionnaires by different researchers represents another possible cause. This study aims to explore these controversies by assessing how gender and education stages impact the changing trend of creativity.

In addition to demographic variables, social variables also affect student creativity. Factors such as social progress and educational reform are relevant (incl. national education funding, educational fund per student, the status of full-time teachers and teachers with senior titles, and the number of digital terminals in schools)(Wu and Ma,2017).First, considering the current social status, regions investing more heavily in education typically display superior educational resources. These better-resourced regions often place greater emphasis on personalized training methods for students(Ma and Zhang,2015). This suggests a connection between the level of education investment and the development of student personality and creativity. Second, the "Opinions on Implementing the Action Plan for Expanding and Improving the Quality of Basic Education in the New Era," issued jointly by three departments of the People's Republic of China including the Ministry of Education, advocates for the expansion and

enhancement of the teacher workforce(Ministry of Education of the People's Republic of China,2023).This policy implies that teachers form the bedrock of education and drive its development. Therefore, building a high-quality, professional teaching corps is fundamental to cultivating innovative talents(Du,2023). Therefore, the status of full-time teachers and those holding senior professional titles likely relates to the advancement of students' creativity. Finally, Huai Jinpeng highlighted digital education's importance in contemporary society during the 2024 Chinese People's Congress and Chinese People's Political Consultative Conference. Digital education offers the potential to enhance educational quality through digitization. It enables teachers to teach creatively and allows students personalized learning experiences, thereby boosting the cultivation of talent innovation ability(Ministry of Education of the People's Republic of China,2024).This indicates the availability of digital terminals can potentially affect the growth of student creativity. Few current studies have directly analyzed the effect of these specific social indicators on student creativity. To test the aforementioned judgments, this study explores the effect of these variables on the changing trend of creativity.

Research Methods

1.Research Tools

Creativity tendency belongs to the category of creative personality. It comprises personality traits such as adventurousness, curiosity, imagination, and challenge power(Liu and Xu ,2014).he tendency towards creativity affects its expression; a strong, positive creativity tendency represents an essential psychological foundation for the development and expression of creativity(Shen et al.,2005).Accordingly, this study selected the "Williams Creativity Disposition Scale"(Lin and Wang,1994;Williams,1967)to explore students' creativity status.F.E.Williams originally developed the scale, which Lin Xingtai later revised. The scale comprises four dimensions: adventurousness, curiosity, imagination, and challenge power, totaling 50 questions. Adventurousness signifies the courage required to face unfamiliar, complex environments while completing tasks. Curiosity represents the desire and inquisitiveness directed towards unfamiliar things, coupled with a spirit for seeking the essence of matters. Imagination involves the capacity to associate unknown concepts based on existing knowledge, thereby rendering abstract ideas concrete. Challenge power denotes the willingness to pursue solutions when confronted with challenges(Hu and Qi , 2016).Higher scores on each dimension, as well as the total score on this scale, indicate stronger creativity.

2.Literature Search and Coding

Collected literature had to satisfy several specific criteria. (1) The measurement instrument employed must be the "Williams Creativity Disposition Scale," either compiled by Williams or revised by Lin Xingtai. (2) Studies needed to specify quantitative indicators, including the mean, standard deviation, and sample size for overall creativity and its four constituent factors. (3) Research participants were required to be students enrolled in high schools, middle schools, or elementary schools in China; student groups identified with mental illnesses or special disabilities were excluded. (4) The cutoff date for literature collection was established as December 2023. (5) In cases where multiple publications utilized the same dataset, their averages were consolidated into a single data point.

To maximize the inclusion of eligible literature, the collection deadline was set at December 2023. This process yielded a total of 71 suitable studies, published between 2009 and 2023. For samples lacking a specified data collection year, the year was estimated by subtracting two

years from the publication year(Hou et al.,2015).Therefore, this study covers the period from 2007 to 2022, spanning 16 years. Excel and SPSS 24.0 software facilitated the encoding, inputting, and analysis of data from the literature meeting the standards (Twenge,2000).The encoding process captured sample size, overall creativity scores, the mean and standard deviation for the four factors, publication year, data collection year, and education stage reported in each study. Gender was utilized as a sub-study variable for separate encoding and database entry.

3.Source of Social Indicators

This study selected five key social indicators obtained from the "China Statistical Yearbook" and the "China Education Statistical Yearbook" (the missing data in the yearbooks can be obtained from the education statistics data of the Ministry of Education). The chosen indicators include national education funding, educational fund per student, the status of full-time teachers and teachers with senior titles, and the number of digital terminals. The study's objective is to explore shifts in creativity and its factors among Chinese primary and secondary students in relation to educational reforms and societal development. A further aim is to deeply analyze the predictive capacity of these social indicators concerning the creativity of Chinese primary and secondary school students.

Research Result

1.The Creativity of Chinese Primary and Secondary School Students Shows an Upward Trend over the Years

Scatter plots (Figure 1-5) were generated to visually depict trends in creativity among Chinese primary and secondary school students between 2007 and 2022. In these plots, the horizontal axis indicates the data collection year, while the vertical axis demonstrates the total creativity score and the individual scores for adventurousness, curiosity, imagination, and challenge power. Figure 1 illustrates an upward trend in the total creativity score for these students during the 2007-2022 period. Similarly, Figures 2-5 demonstrate that the mean values for the factors of adventurousness, curiosity, imagination, and challenge power increased over this timeframe. These findings collectively suggest a gradual enhancement in the overall creativity level of Chinese primary and secondary school students throughout the studied years.

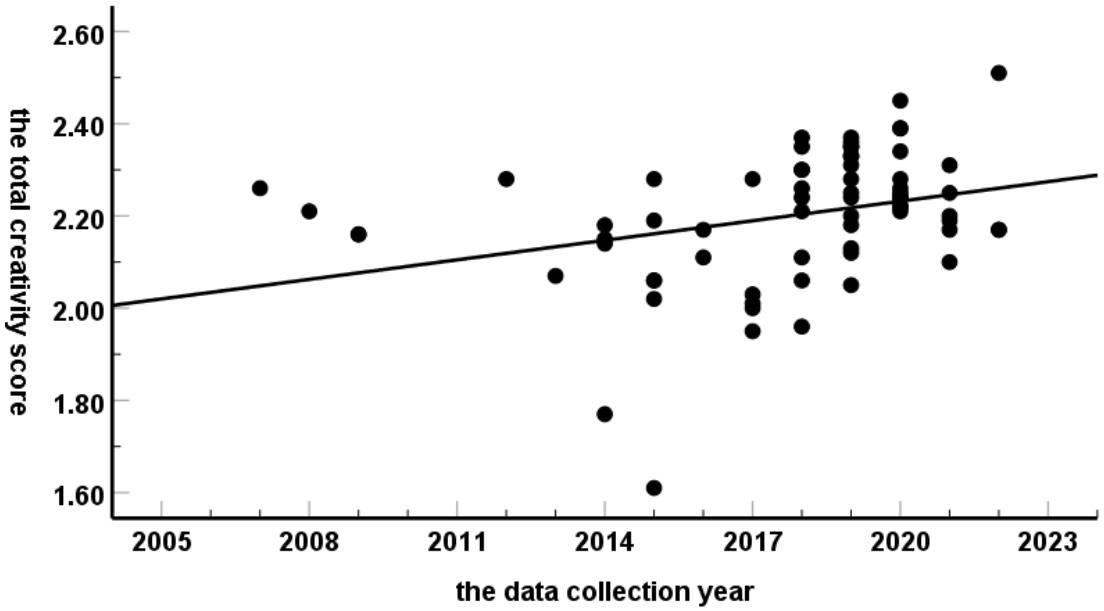


Figure 1 2007—2022 The trend of the average score of creativity in primary and middle school students in China with the change of years

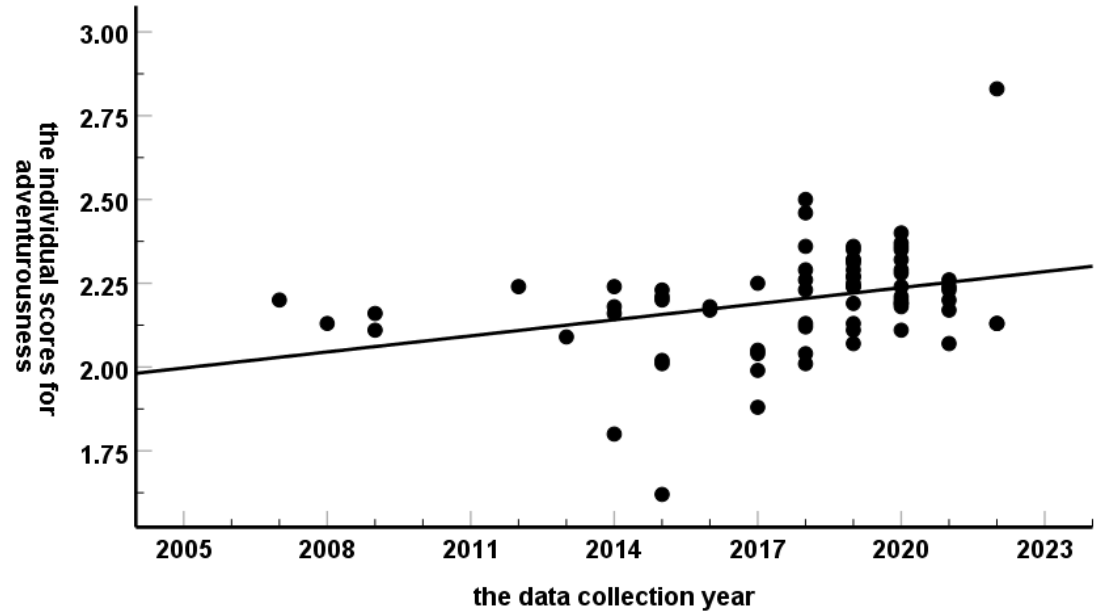


Figure 2 2007—2022 The trend of the average score of adventurousness in primary and middle school students in China with the change of years

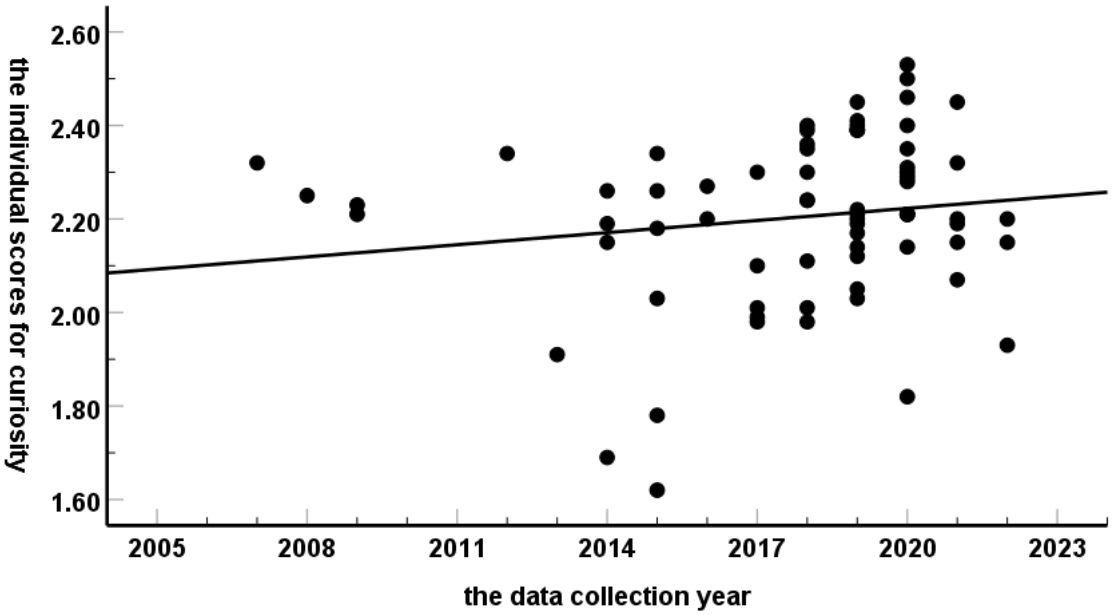


Figure 3 2007—2022 The trend of the average score of curiosity in primary and middle school students in China with the change of years

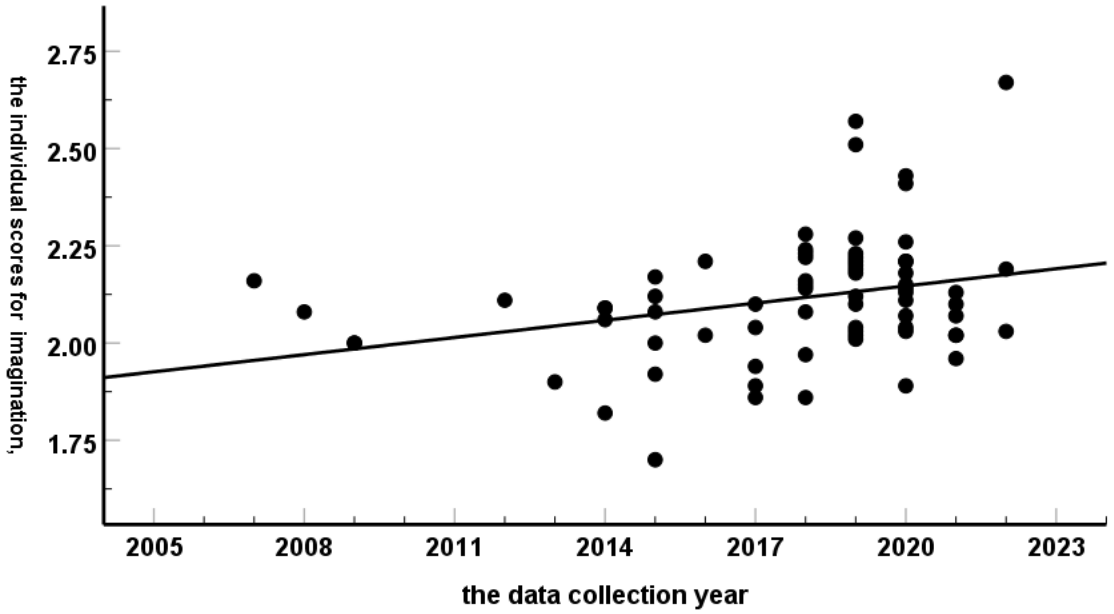


Figure 4 2007—2022 The trend of the average score of imagination in primary and middle school students in China with the change of years

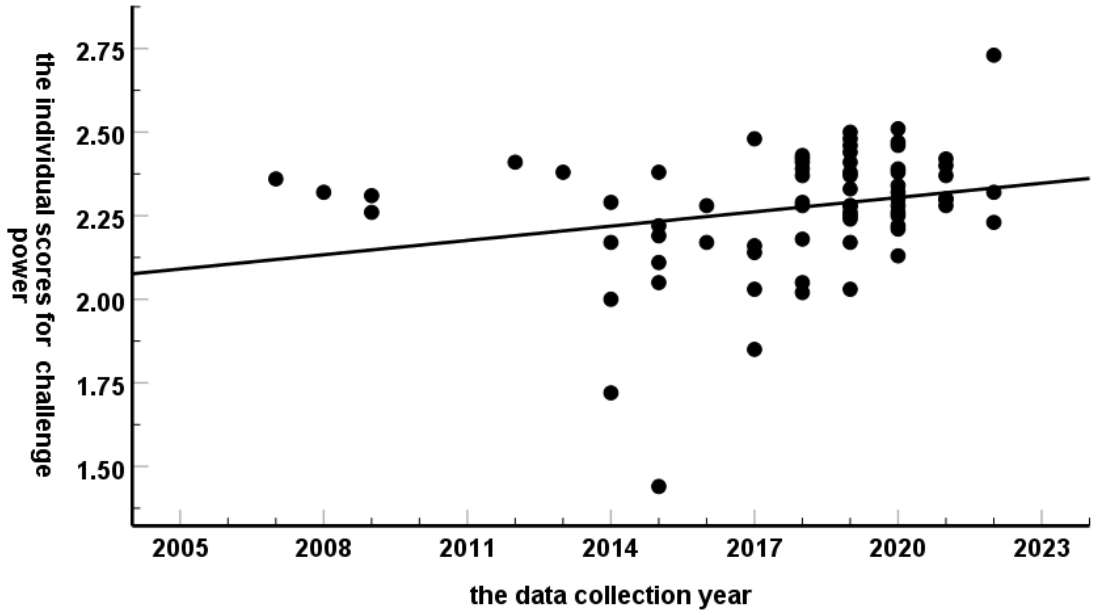


Figure 5　2007—2022 The trend of the average score of challenge power in primary and middle school students in China with the change of years

To determine the year effect on creativity among Chinese primary and secondary school students, a simple regression analysis was performed. The results from this analysis indicate a significant positive predictive effect（β=0.32，P=0.007；F=7.68，P<0.05） of years on the average creativity score, explaining 10% of the variation. Years also significantly and positively predicted changes in average adventurousness（β=0.33，P=0.006；F=8.14，P<0.05）, accounting for 10.6% of its variation. In addition, significant positive prediction by years was determined to be capable of explaining changes in average imagination（β=0.29，P=0.013；F=6.54，P<0.05）, accounting for 8.7% of its variation. Changes in average challenge power were also significantly and positively predicted by years(β=0.25，P=0.038；F=4.47，P<0.05), which explained 6.1% of the variation. However, years did not appear as a significant predictor for changes in average curiosity(β=0.15，P=0.199；F=1.68，0.05<P<0.2).

In addition, weighted least squares regression analysis was conducted in this study to reduce the effect of varying sample sizes on the research results. This analysis treated the data collection year as the independent variable, with creativity and its four factor means representing the dependent variables (results detailed in Table 1). After controlling for sample size, the analysis confirmed that years remained a significant positive predictor of the average total creativity score among primary and secondary school students(β=0.25，P=0.037；F=4.55，P<0.05), accounting for 6.2% of its variation. Besides curiosity and imagination, years also demonstrated a significant predictive effect on adventurousness and challenge power in this weighted analysis. Based on the preceding results, a significant upward trend defined the overall creativity level of Chinese primary and secondary school students from 2007 to 2022.

Table 1 The creativity score and correlation of each factor with changing years in primary and middle school students

Factor	Uncontrolled sample size		Control sample size	
	r	r^2	β	r^2
creativity	0.32^{**}	0.10	0.25^{*}	0.06
adventurousness	0.33^{**}	0.11	0.28^{*}	0.08
curiosity	0.15	0.02	0.11	0.01
imagination	0.29^{*}	0.09	0.16	0.02
challenge power	0.25^{*}	0.06	0.23^{*}	0.06

Note: +0.05<P<0.1, *P<0.05, **P<0.01, ***P<0.001. r is the correlation coefficient of uncontrolled sample size,β is the standardized coefficient of control sample size, r2 is the coefficient of determination, the same below.

2.The Creativity Level of Chinese Primary and Secondary School Students Showed a Moderate Upward Trend Over the time

Building on the finding that creativity levels among Chinese primary and secondary school students increased from 2007 to 2022, we calculated the effect size variable d to quantify the magnitude of this change(Twenge,2007;Xin and Zhang,2009).The calculation involved several steps: first, conducting regression analysis utilizing weighted sample sizes to derive the regression equation; second, employing this equation to calculate , M_{2007} and M_{2022} estimates; and finally, substituting these resultant values into formula 1 to obtain the value of d.

$$d = \frac{M_{2007} - M_{2022}}{M_{SD}} \qquad \text{（formula1）}$$

Table 2 presents the calculated average total creativity scores, which were 2.55 in 2007 and 2.70 in 2022 for Chinese primary and secondary school students. An increase of 0.15 occurred over the past 16 years in the average total creativity score, translating to an increase of 0.68 in standard deviation units (d) based on an average standard deviation of 0.22. Calculations for the component factors indicated the following increases: adventurousness rose by 0.18 (d = 0.72, avg. SD = 0.25); curiosity increased by 0.06 (d = 0.24, avg. SD = 0.25); imagination saw an increase of 0.09 (d = 0.31, avg. SD = 0.29); and challenge power grew by 0.18 (d = 0.72, avg. SD = 0.25). We interpreted these effect sizes utilizing Cohen's criteria(Cohen,2013),where d>0.8 indicates a "large effect size," 0.8>d>0.5 signifies a "medium effect size," and 0.5>d>0.2 represents a "small effect size." In this study, the changes observed for the total score of creativity and its factors of adventurousness and challenge power are in the medium effect size range. In comparison, the changes associated with the factors of curiosity and imagination correspond to small effect sizes. This pattern signifies a significant increase in the total score of creativity, adventurousness, and challenge power among Chinese primary and secondary school students over the past 16 years, accompanied by a more modest rise in the factors of curiosity and imagination. In essence, the creativity level of Chinese primary and secondary school students displayed an upward trend.

Table 2 The amount of change in the creativity level of primary and middle school students over the years

Factor	M_{2007}	M_{2022}	M_{OC}	M_{SD}	d
creativity	2.55	2.70	0.15	0.22	0.68
adventurousness	2.76	2.94	0.18	0.25	0.72
curiosity	1.21	1.27	0.06	0.25	0.24
imagination	2.42	2.51	0.09	0.29	0.31
challenge power	2.27	2.45	0.18	0.25	0.72

3.Changes in Creativity Levels and Score Differences among Chinese Primary and Secondary School Students of Different Genders Over the Time

This study analyzed 19 literature reports containing gender-specific data (4,454 boys and 4,756 girls)to explore gender-based changes and differences in creativity among Chinese primary and secondary school students over the specified period. Analysis utilizing same-size weighting indicated that the predictive effect of years on the total creativity scores was not significant for either male or female students (Table 3, Figures 6 and 7). Nevertheless, a visual inspection of the scatter plots suggested an increase over the years in total creativity scores for both male and female groups.

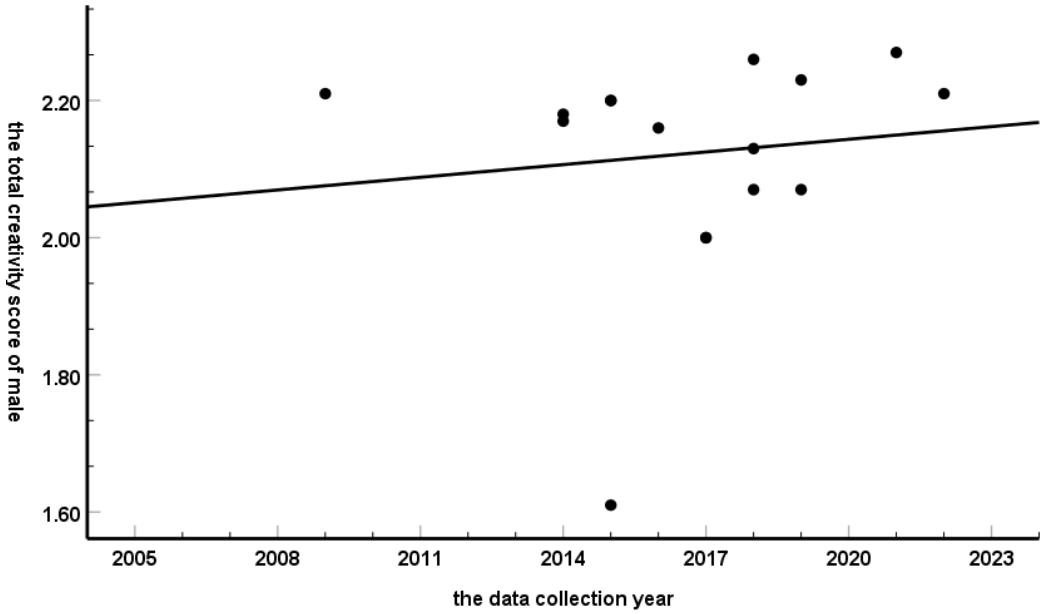


Figure6 2007—2022The trend of the average total score of creativity in primary and secondary school male with respect to the changing years

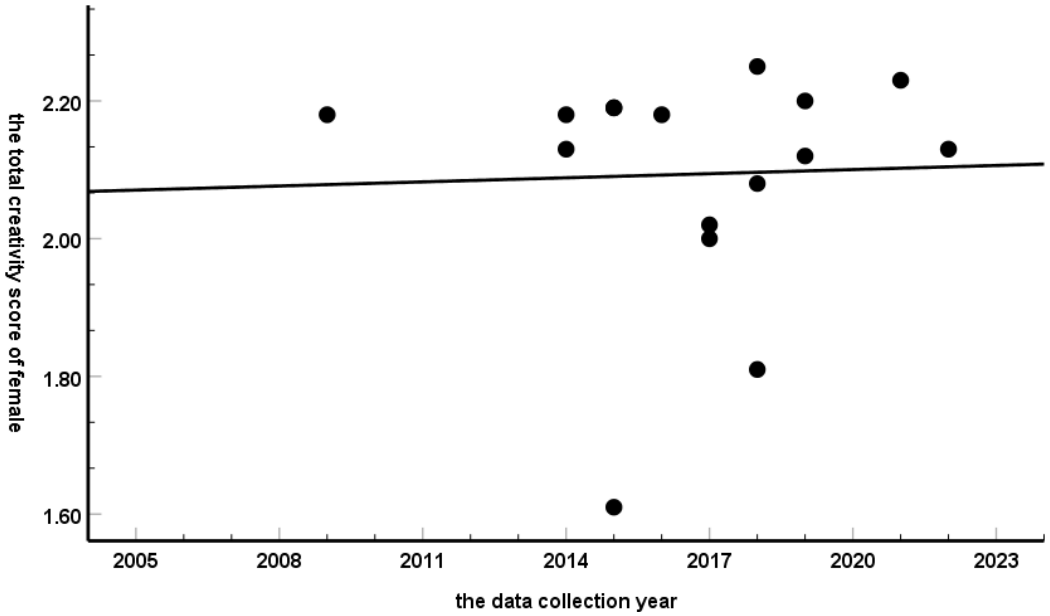


Figure7 2007—2022The trend of the average total score of creativity in primary and secondary school female with respect to the changing years

Table 3 The changes of creativity and its factors in primary and middle school students of different genders with the years

Factor	male				female			
	β	r^2	M_{SD}	d	β	r^2	M_{SD}	d
creativity	0.23	0.05	0.28	0.60	0.19	0.04	0.28	0.42
adventurousness	0.23	0.07	0.25	0.78	0.12	0.01	0.27	0.29
curiosity	0.27	0.07	0.28	0.88	0.23	0.05	0.28	0.56
imagination	0.15	0.02	0.27	0.29	0.16	0.03	0.29	0.27
challenge power	0.28	0.08	0.28	1.07	0.21	0.04	0.28	0.65

Note: +0.05<P<0.1, *P<0.05, **P<0.01, ***P<0.001. r is the correlation coefficient of uncontrolled sample size,β is the standardized coefficient of control sample size, r2 is the coefficient of determination, the same below.

To measure the magnitude of change for each gender, effect sizes (d) for creativity and its four factors were calculated utilizing the previously described method, with results demonstrated in Table 3. The data demonstrated that the increase in the male students' total creativity score corresponded to a medium effect (d = 0.60), while the increase for female students represented a small effect (d = 0.42). Regarding adventurousness, males exhibited an increase equating to a near-large effect size (d = 0.78), which contrasted with a small effect size increase observed for females (d = 0.28). Increases in curiosity represented a large effect for males (d = 0.88) and a medium effect for females (d = 0.56). Imagination increases demonstrated a small effect for both male and female students. For challenge power, the increase among males indicated a small effect, whereas the increase among females suggested a medium effect. These effect sizes demonstrate an upward trend in creativity levels for both male and female students in primary and secondary schools over the past 13 years, while the upward trend appears more significant for male students.

Moreover, the study conducted a further exploration into the difference in average creativity between male and female primary and secondary school students during this period. Calculation of $\bar{d}$ as performed utilizing the male cohort as the control group and the female cohort as the experimental group, as outlined in formula 2. The resulting calculations presented in Table 4 indicate negative values for the total scores of imagination and challenge power, while creativity, adventurousness, and curiosity yielded positive values; this suggests higher scores for males than females in the latter three areas. Applying Cohen's (1992) criteria, only the average effect size for curiosity reached the small effect size threshold. Effect sizes for creativity and the other factors remained below the small effect size benchmark, implying that overall gender differences in the total scores of creativity and its factors among Chinese primary and secondary school students were not significant during this timeframe.

$$\bar{d} = \sum W_i d_i / \sum W_i \qquad \text{（formula 2）}$$

$$W_i = 2N_i / \left(8 + d_i^2\right)$$

$$d = (M_{male} - M_{female}) / SD$$

$$\mathrm{S}D = \sqrt{\left[(n_e - 1)S_e^2 + (n_c - 1)S_c^2\right] / (n_e + n_c - 2)}$$

Table 4 The average effect size of creativity and gender differences among Chinese primary and secondary school students

factor	creativity	adventurousness	curiosity	imagination	Challenge power
$\bar{d}$	0.05	0.06	0.20	-0.09	-0.03

4.The Changes in Creativity Levels and Score Differences among Chinese Primary and Secondary School Students in Different Education Stages over the Time

In addition to gender, education stage is recognized as a factor potentially affecting students' creativity. Therefore, this study performed an analysis analyzing the relationship between creativity and its four factors among students grouped by year and education stage. Data adjusted utilizing same-size weighting indicated that years could not significantly predict positive changes in creativity and its factors（P>0.1）for primary and secondary high school students collectively. Years did, however, significantly and positively predict changes specifically in creativity（P=0.08） and adventurousness （P=0.08）among high school students, though a significant positive predictive effect was absent for the factors of curiosity, imagination, and challenge power （P>0.1）in this high school group.

According to the aforementioned methods, effect sizes for the changes in creativity and its four factors over time were obtained for students in different education stage groups (Table 5). The changes in creativity among primary, middle, and high school students all corresponded to small effect sizes, while high school students displayed the largest change magnitude. With respect to adventurousness, primary school students demonstrated changes belonging to the medium effect size category, while middle and high school students demonstrated changes

considered a small effect; therefore, primary school students experienced the largest changes in adventurousness. Middle school students registered no significant changes in curiosity, whereas changes in curiosity among primary and high school students fell into the small effect size category, with primary school students exhibiting the largest change. For imagination, the changes among primary school students constituted a small effect size, but changes were not significant for middle and high school students, positioning primary school students as having the largest change in imagination. Finally, the changes in challenge power among high school students aligned with a medium effect size, while changes for primary and middle school students were not significant, indicating high school students had the largest change in challenge power.

Table 5 The changes of creativity and its factors in primary and middle school students of different education stage with the years

factor	education stage	M_{2007}	M_{2022}	M_{OC}	M_{SD}	d
creativity	primary school	2.16	2.23	0.08	0.22	0.36
	primary high school	2.48	2.57	0.09	0.22	0.41
	secondary high school	1.53	1.65	0.12	0.23	0.52
adventurousness	primary school	1.21	1.36	0.15	0.25	0.6
	primary high school	1.95	2.04	0.09	0.26	0.35
	secondary high school	3.06	3.2	0.14	0.26	0.54
curiosity	primary school	2.23	2.16	-0.07	0.24	-0.29
	primary high school	1.29	1.30	0.01	0.26	0.04
	secondary high school	2.34	2.43	0.09	0.26	0.35
imagination	primary school	1.64	1.70	0.06	0.26	0.23
	primary high school	1.33	1.28	-0.05	0.28	-0.18
	secondary high school	2.00	2.02	0.02	0.29	0.07
challenge power	primary school	1.87	1.87	0.00	0.24	0.00
	primary high school	2.72	2.76	0.04	0.27	0.15
	secondary high school	2.24	2.39	0.15	0.24	0.63

5.The Changes in Student Creativity Trends Can be Significantly or Marginally Influenced by National Education Funding, Educational Fund per Student, the Status of Full-time Teachers and Teachers with Senior Titles, and the Number of Digital Terminals.

The results presented earlier demonstrate an upward trend in the creativity levels among Chinese primary and secondary school students across the recent 16 years. A crucial question is thus posed: does this trend correlate with social changes? Following established research methods(Xin et al.,2021),cross-sectional history not only to defines the trends of creativity and its associated factors over time but also facilitates understanding the effect of social change by analyzing relationships between these trends and social indicators. Controlling for sample size indicates specific relationships, as detailed in Tables 6 and 7. National education funding positively and significantly predicts changes in overall creativity(P=0.023), adventurousness(P=0.012), and challenge power(P=0.029) , while it lacks a significant positive predictive effect on imagination and curiosity. There is a significant positive prediction from the educational fund per student to changes in creativity(P=0.036) and adventurousness(P=0.031); its effect on challenge power (P=0.066) is marginally significant, while no significant positive prediction exists for curiosity and imagination. Significant positive predictions for changes in

creativity（P=0.000）, adventurousness（P=0.000）, curiosity（P=0.024）, imagination（P=0.020）, and challenge power （P=0.001）are associated with the number of full-time teachers. The presence of teachers holding senior titles significantly predicts changes in creativity（P=0.003）, adventurousness（P=0.002）, and challenge power（P=0.030）. Besides, it demonstrates a marginally significant positive predictive relationship with curiosity（P=0.057） and imagination （P=0.064）. Digital terminal availability significantly predicts changes in creativity（P=0.025）, adventurousness（P=0.016）, and challenge power（P=0.036）, yet demonstrates no significant positive predictive effect on curiosity and imagination. In essence, these findings suggest relationships connect both national education funding and the educational fund per student to creativity and factors including adventurousness, challenge power, and imagination. Connections are evident between both full-time teachers and teachers with senior titles and creativity along with its four constituent factors. Digital terminals demonstrate a relationship with creativity as well as its adventurousness and challenge power components.

To further explore the effect of social variables on creativity among this student population, lagged correlation analysis can be employed, building on previous research(Xin,Z and Xin,S.,2017).This specific approach involves matching the five social indicators against creativity and its factors from one, three, and five years prior, respectively, for analysis. The resulting data indicated that national education funding and the educational fund per student from one year prior could significantly and positively predict changes in creativity, adventurousness, and challenge power, though not significantly for curiosity and imagination. Full-time teacher numbers significantly and positively predicted changes across creativity and all its factors. Teachers with senior titles and the availability of digital terminals were significant positive predictors for changes in creativity, adventurousness, curiosity, and challenge power, but lacked a significant predictive effect on imagination. Looking back three years, national education funding and the educational fund per student positively predicted shifts in creativity, adventurousness, and challenge power, without indicating a predictive effect on curiosity and imagination. The number of full-time teachers positively predicted changes in creativity, adventurousness, imagination, and challenge power, but demonstrated no significant predictive relationship with curiosity. Teachers holding senior titles displayed no significant predictive effect on creativity or its factors at the three-year lag. Digital terminal access only offered a significant positive prediction for the adventurousness factor, lacking significant predictive power for creativity and the other three factors over this timeframe. Extending the lag to five years, national education funding, the educational fund per student, and digital terminal numbers significantly and positively predicted changes in creativity, adventurousness, and challenge power, yet did not significantly predict curiosity and imagination. The count of full-time teachers solely had a significant positive predictive effect on adventurousness, indicating no significant prediction for creativity or other factors. Once again, teachers with senior titles demonstrated no significant predictive effect on creativity or its factors at this lag. Taking all time points into account, national education funding, educational fund per student, the number of full-time teachers, and the number of digital terminals represent key factors predicting or affecting the creativity and its associated factors among Chinese primary and secondary school students.

Table 6 Predictive effect of social indicators on the change of creativity in the current year, 1 year ago, 3 years ago and 5 years ago

Social indicators	Current year creativity		1 year ago creativity		3 years ago creativity		5 years ago creativity	
	β	r^2	β	r^2	β	r^2	β	r^2
National Education Funding	0.27*	0.06	0.28*	0.07	0.26*	0.05	0.30*	0.08
Educational Fund per Student	0.25*	0.05	0.30*	0.08	0.31**	0.08	0.35**	0.11
the Status of Full-time Teachers	0.43***	0.17	0.42***	0.16	0.36**	0.11	0.18	0.02
Teachers with Senior Titles	0.35**	0.11	0.25*	0.05	-0.03	-0.01	-0.05	-0.01
the Number of Digital Terminals	0.28*	0.06	0.34**	0.10	0.20	0.03	0.34*	0.10

Table 7 Predictive effect of social indicators on the change of creativity in the current year, 1 year ago, 3 years ago and 5 years ago

Social indicators	adventurousness		curiosity		imagination		Challenge power	
	β	r^2	β	r^2	β	r^2	β	r^2
current year								
National Education Funding	0.30*	0.08	0.11	0.00	0.17	0.02	0.26*	0.05
Educational Fund per Student	0.26*	0.05	0.13	0.00	0.16	0.01	0.22*	0.03
the Status of Full-time Teachers	0.42***	0.17	0.27*	0.06	0.28*	0.06	0.40**	0.15
Teachers with Senior Titles	0.37**	0.13	0.23+	0.04	0.23	0.04	0.26+	0.06
the Number of Digital Terminals	0.29*	0.07	0.18	0.02	0.16	0.01	0.26*	0.05
1 year ago								
National Education Funding	0.31**	0.08	0.13	0.00	0.18	0.02	0.26*	0.05
Educational Fund per Student	0.31**	0.08	0.17	0.01	0.18	0.02	0.27*	0.06
the Status of Full-time Teachers	0.43***	0.17	0.25*	0.05	0.28*	0.06	0.40**	0.15
Teachers with Senior Titles	0.32**	0.09	0.08+	-0.01	0.14	0.01	0.22+	0.04
the Number of Digital Terminals	0.35**	0.11	0.18**	0.02	0.22	0.03	0.32**	0.09
3 years ago								
National Education Funding	0.29*	0.07	0.11	-0.00	0.17	0.02	0.24*	0.04
Educational Fund per Student	0.33**	0.10	0.16	0.01	0.20+	0.03	0.30*	0.08
the Status of Full-time Teachers	0.40***	0.15	0.16	0.01	0.25*	0.05	0.35**	0.11
Teachers with Senior Titles	0.06	-0.01	-0.13	0.01	0.03	-0.01	-0.03	-0.01
the Number of Digital Terminals	0.27*	0.06	-0.02	-0.02	0.16	0.01	0.15	0.01
5 years ago								
National Education Funding	0.32**	0.09	0.15	0.01	0.17	0.02	0.30*	0.08
Educational Fund per Student	0.36**	0.12	0.19	0.02	0.21+	0.03	0.34**	0.11
the Status of Full-time Teachers	0.25*	0.05	-0.00	-0.01	0.14	0.01	0.18	0.02
Teachers with Senior Titles	0.02	-0.1	-0.12	0.00	-0.07	-0.01	-0.05	-0.01
the Number of Digital Terminals	0.27*	0.06	0.11	-0.01	0.20	0.02	0.32*	0.09

Discussion and Suggestions

This study organized creativity tendency data collected from 18,913 Chinese primary and secondary school students over the preceding 16 years. Its purpose was to analyze the temporal trend of creativity changes and identify factors influencing these changes in this demographic. The obtained results were analyzed to draw conclusions.

1.With the Continuous Advancement of Education Reform, the creativity of Chinese primary and secondary school students shows an upward trend

Cross-sectional historical meta-analysis research findings indicated a significant positive correlation between the average creativity of Chinese primary and secondary school students and the passage of years. In addition, the four creativity factors demonstrated significant or marginally significant positive correlations with years, suggesting a gradual improvement in student creativity. These results imply that ongoing national education reform efforts lead educators to progressively understand and apply concepts and strategies for cultivating youth creativity in both theory and practice. Therefore, an enhancement in students' creativity appears as an inevitable trend to a certain extent. From a theoretical standpoint first, representative scholars L.S.Vygotsky and John Steiner in social and cultural theory propose that creativity development is shaped by the surrounding environmental system, forming progressively through environmental interaction(Steiner,2009;Vygotsky,2004).The creative process and creativity itself do not arise solely in individuals; instead, their formation occurs through interactions between individuals and the socio-cultural situation. Stated differently, student creativity is generated and developed through continuous environmental interaction, positioning education as the mechanism for nurturing creators(Reckwitz,2018). Therefore, students interacting with progressively enhancing educational settings during continuous educational reform signifies their creativity is constantly developing in that environment. Secondly, concerning practical aspects, educational policies affect not only school practices but also student creativity development at a macro level(Salamah et al.,2023).Meanwhile, at the micro level, teachers can motivate student creativity development. The improvement of teachers' teaching concepts(Chen and Wang,2010)and their practical capabilities(Ye,2017)can accordingly enhance the effectiveness of cultivating student creativity. China is currently adopting a comprehensive perspective in its education policies and advancing teaching reforms, which aligns with the observation of gradually improving student creativity.

Therefore, managing this new era necessitates an unswerving commitment to the path of independently cultivating top innovative talents. Promoting the discovery of innovative talents, cultivating and developing new quality productivity, and realizing the Chinese path to modernization should be pursued through the following approaches. Firstly, aligning with educational policies, the education system must shift its inclination towards exam-oriented education by reforming examination and evaluation systems(Wang et al.,2023);this cultivates student diversity. Secondly, a change in mindset is required for teachers, who need a comprehensive understanding of student creativity in their teaching, thereby narrowing the gap between institutional objectives and creative outcomes(Chu et al.,2008).Finally, enhancing teacher capabilities through appropriate training and a scientific evaluation system is crucial for improving their practical teaching skills(Fan,2017).

2.Increase the Supply of Educational Resources and Promote the Enhancement of Creativity among Chinese Primary and Secondary School Students

This study determined that changes in student creativity and its four factors could be predicted, either significantly or marginally, by both national education funding and the educational fund available per student. Specifically, data concerning national education funding and per-student educational funds from the current year, as well as 1, 3, and 5 years prior, demonstrated significant or marginal predictive power regarding shifts in student creativity and its components. These findings suggest that augmented investment in the education sector can, to a certain degree, stimulate the growth of students' creative capacities. Measuring the supply of educational resources often relies on the government's financial commitment to education; increasing this investment is associated with enhanced human capital development across educational levels and improvements in labor force quality(Hao and Min,2022;Yang et al.,2024).Therefore, a pattern can be observed where regions demonstrating high government educational investment tend to achieve higher economic development and have relatively better educational resources. Schools and teachers in such areas thus gain the capacity to employ a wider array of human and material resources, utilizing the latest educational technologies and methodologies(Ma and Zhang,2015).Such an environment helps broaden students' perspectives, thereby promoting their creative development.

Significant positive predictions for changes in creativity and its factors were associated with the number of full-time teachers in the current year and the preceding year, according to this study. In addition, the presence of teachers holding senior titles, both currently and one year ago, demonstrated a significant positive predictive effect on overall creativity and specific factors such as adventurousness, curiosity, and challenge power. The overall trend indicates that student creativity and its related factors continually improve as the numbers of full-time teachers and those with senior titles increase. Expanding and enhancing the quality of basic education was proposed as an action item during the 2024 Chinese People's Congress and Chinese People's Political Consultative Conference, with specific measures including the growth and improvement of the teacher workforce(Ministry of Education of the People's Republic of China,2024).China's compulsory education system also aims for high-quality, balanced development by 2035, placing emphasis on the connotation and quality improvement. Optimizing the supply of qualified compulsory education teachers is therefore critical(Zhou et al.,2023).Besides, drawing from "professional capital theory," some researchers argue that cultivating top-tier innovative talent necessitates teachers with the relevant competencies. Developing these competencies moves beyond reliance solely on "human capital," incorporating "professional capital (human capital, social capital, decision-making capital)" to advance teacher professional development(Tian and Lu,2024). Full-time teachers and educators with senior titles, when viewed through this lens, appear better equipped than part-time teachers, substitute teachers, or those with junior titles to cultivate top-notch innovative abilities in students.

An additional finding from this study indicated that the quantity of digital terminals available currently, one year ago, and five years ago significantly and positively predicted changes in student creativity, particularly impacting factors such as adventurousness and challenge power. In essence, a greater availability of digital terminals appears beneficial for enhancing student creativity. The characteristics of digital terminals include variability, practicality, and creative potential. Teaching utilizing digital terminals places greater demands on students' innovation and logical association skills, as the curriculum itself often incorporates innovative

requirements(Wang,2022).This process implicitly cultivates students' creative thinking, curiosity, and imagination. Students additionally enhance their adventurousness and challenge power when they employ digital terminals for problem-solving(Liu,2008).Considering the progression of time, the goalpost moving from no equipment to complete saturation highlights how the continuous expansion of digital terminal resources effectively supports the cultivation of student creativity.

The preceding analysis demonstrates that national education funding, per-student education funds, full-time teacher numbers, the prevalence of senior-titled teachers, and the availability of digital terminals each predict changes in student creativity to varying extents. This correlation suggests that ongoing education reforms, through optimizing educational resources, can more effectively cultivate the development of students' creative potential. Therefore, several actionable measures can be taken as follows: First, regarding education fund supply, sustaining a stable increase in investment for basic education is crucial(Wang et al.,2020).Achieving the objective of a high-quality education system also necessitates larger-scale, high-level funding investments commensurate with this task to ensure the education industry's sustainable development(Du and Yang,2023).Second, concerning human resource supply, efforts must extend beyond merely increasing the quantity of full-time and senior-titled teachers; building a high-quality teaching team aligned with national standards is essential. Promoting both the quantity and quality of teachers is therefore necessary. China, managing its vast teaching force, should establish structured teacher groups reflecting individual school needs and adjust the proportion of professional titles among primary and secondary teachers based on demographic shifts, thereby meeting the demands of economic development and population changes(Gao,2016).Finally, addressing digital terminal supply requires increasing the total number and growth rate, while prioritizing allocation to rural areas in central and western regions, ethnic border areas, and remote, poverty-stricken locations(Cai et al.,2024). Strengthening the balance of digital resource distribution across regions, between urban and rural settings, and among schools is vital to help students from diverse backgrounds access equitable educational resources, develop their creativity, and ensure every child can become the innovative talent China needs.

3.Respect Students' Individual Characteristics and Enhance the Development of Creativity among Chinese Primary and Secondary School Students

While this research determined no significant overall impact of gender on student creativity, boys exhibited a more significant increase in creativity over time compared to girls. This conclusion aligns with explanations offered by "evolutionary developmental psychology," which hypothesizes that males historically required extensive spatial cognitive abilities for managing unfamiliar environments or hunting, leading to greater energy and aggressiveness(Buss,2024). [89] Accordingly, boys may display an advantage in creativity development in modern education, resulting in slightly faster progress than girls. Future educational practices should consider implementing gender-specific activities for the unique psychological characteristics of boys and girls, aiming to balance and promote creative development in both groups.

Besides, the study indicated that time (years) had a more significant positive predictive effect on the creativity of high school students compared to primary and middle school students. High school students demonstrated the largest changes in overall creativity and the challenge power factor when analyzing the amplitude of change; whereas, primary school students displayed the most significant changes in adventurousness, curiosity, and imagination factors. Survey data

indicating a significant growth trend in creativity during grades 4-6 of primary school can be understood through three aspects(Zhang et al.,2020).First, accumulating basic knowledge and experience offers a foundation for creative development. Second, the development of abstract logical thinking capacity enables primary students to internalize prior knowledge and experiences. Third, language functions mature with increasing grade level, allowing previously abstract logical thought to be expressed with greater sophistication. Therefore, creativity factors demonstrate increased sensitivity to change during primary school, explaining the substantive shifts in adventurousness, curiosity, and imagination. Middle school students experiencing significant physical and mental maturation during adolescence. Their creativity may increase somewhat as they become familiar with and adapt to the middle school environment and its regulations, while this increase is not typically significant. Following the foundational period in primary school and stabilization in middle school, students' creative thinking reaches greater maturity in high school. High school training requirements prioritize cultivating students' abilities to discover, propose, and evaluate problems, followed by problem-solving skills and critical/reflective capacities, finally aiming to establish innovative thinking patterns(Guo,2016). As the demands for creativity cultivation are higher for high school students than primary and middle school students, their creativity scores are understandably higher. In essence, cultivating student development necessitates respecting their individual differences and age-specific characteristics to achieve comprehensive growth.

For this study, a cross-sectional historical meta-analysis methodology was employed to collect and analyze data from recent years, thereby indicating trends in phenomena over this period. The research also utilized direct or lagged correlation analyses to connect macro-level social variables with micro-level individual variables(Twenge,2000).This approach allowed for an analysis and explanation of how certain societal environments affect the creativity of Chinese primary and secondary students. While these findings can offer valuable directions for educational scholars, the generalizability of the results faces certain constraints. The cross-sectional historical meta-analysis method permits the collection of longitudinal developmental data on student creativity rapidly and at minimal cost, effectively illustrating changes over time. However, the stringent criteria for literature quality in this method result in a relatively small pool of citable studies, which thus limits the extent to which the research findings can be generalized(Hou,et al.,2014).Future research could continuously monitor the availability of includable literature to potentially enhance the generalizability of research results derived from cross-sectional historical meta-analyses.

Data availability

All the data used in this study are publicly accessible. If necessary, you can contact the corresponding author for further inquiries.

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Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Figure legend

Figure 1　2007—2022 The trend of the average score of creativity in primary and middle school students in China with the change of years

Figure 2　2007—2022 The trend of the average score of adventurousness in primary and middle school students in China with the change of years

Figure 3　2007—2022 The trend of the average score of curiosity in primary and middle school students in China with the change of years

Figure 4　2007—2022 The trend of the average score of imagination in primary and middle school students in China with the change of years

Figure 5　2007—2022 The trend of the average score of challenge power in primary and middle school students in China with the change of years

Figure6　2007—2022The trend of the average total score of creativity in primary and secondary school male with respect to the changing years

Figure7　2007—2022The trend of the average total score of creativity in primary and secondary school female with respect to the changing years

Table 1　The creativity score and correlation of each factor with changing years in primary and middle school students

Table2　The amount of change in the creativity level of primary and middle school students over the years

Table 3　The changes of creativity and its factors in primary and middle school students of different genders with the years

Table 4　The average effect size of creativity and gender differences among Chinese primary and secondary school students

Table 5　The changes of creativity and its factors in primary and middle school students of different education stage with the years

Table 6　Predictive effect of social indicators on the change of creativity in the current year, 1 year ago, 3 years ago and 5 years ago

Table 7　Predictive effect of social indicators on the change of creativity in the current year, 1 year ago, 3 years ago and 5 years ago