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The Impact of Private Supplementary Tutoring Time on Adolescents ' Scientific Literacy in Science Education: An Empirical Comparative Study from China and South Korea

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Abstract
Along with the rapid development of knowledge-based economy, the competition in education has become more and more intense, and the system of "shadow education" characterized by private extracurricular tutoring has been expanding in East Asian societies where peer pressure gathers, especially in representative countries such as China and South Korea, but it is not clear how the investment of time in shadow education affects young people's performance in core literacy. There is a relative lack of empirical analysis of shadow education in basic education, and even rarer research on shadow education involving science subjects and their time investment, which cannot provide reliable guidance for government intervention in science shadow education. Based on the PISA2018 Chinese and Korean

assessment data, multiple linear regression equations were set up to analyze the effects of the time spent on science shadowing on adolescents' scientific literacy based on the full consideration of the endogenous factors, and it was found that: the time spent on science shadowing is a key factor influencing the adolescents' performance in scientific literacy; the effects of the time spent on science shadowing on the Chinese and Korean adolescents' scientific literacy differ significantly, and it shows a significant positive effect on the Korean students. There are significant differences in the effects of science shadow education on the scientific literacy of Chinese and Korean youths, with a significant positive effect on Korean students but a significant negative effect on Chinese students; science shadow education has the social risk of expanding the inequality of education. For the future direction of science shadow education in basic education, we should objectively and rationally evaluate the feedback effect of the variable "time" on the performance of youth's scientific literacy based on the measurement of learning efficiency, and guide the stakeholders to shift their attention from "more learning time" to "high-quality learning". This will guide stakeholders to shift their attention from "more study time" to "quality study time", dispel the social illiteracy under the pressure of educational involution and peer pressure in China, and increase and expand the ground for the reform of the "double reduction" policy.

Key words: science education; scientific literacy; shadow education; private supplementary tutoring; multiple linear regression model

1. Introduction

As a supplement to the school education system, shadow education plays an important role in helping students from different social strata to improve their qualities and enhance the competitive strength of their peers. Especially in East Asian societies, where competition in education is fierce, shadow education has developed rapidly and become very common due to the influence of traditional Confucian cultural concepts and the pressure of selection for higher education examinations. However, the disorderly expansion of shadow education has also given rise to all kinds of disorder, whether it can really effectively make up for certain gaps or deficiencies in school education, and whether it is a "sword" to enhance students' academic achievements or a "trap" to increase students' academic pressure, etc. have been brought to the forefront. The issues of whether it is a "sword" or a "trap" that increases students' academic pressure are gradually being brought to the forefront, and the anxiety it brings to education is seriously affecting the positive cycle of the education ecology.

Science and technology are the first productive forces, and talents are the first resources. We carry the ambition of the industrial age all the way to the wild ride so far, the Internet of things, big data, artificial intelligence, genetic reorganization and other new technologies emerge, completely subverted the traditional mode of human existence. On the way from "big

country" to "strong country", what kind of talents do we need? As a matter of fact, the answer to this question is beginning to emerge under the strategy of scientific socialism. Science education, as an important aspect of China's basic education, is an important foundation for enhancing the country's scientific and technological competitiveness, cultivating innovative talents, and improving the scientific quality of young people. Cultivating a group of outstanding elites with a forward-looking vision of the future and strong insight into the intelligent society is an important bargaining chip for the country's scientific and technological development and participation in global political games. According to the results of PISA2018, science shadow education is particularly prevalent in East Asian societies. However, compared with the research on science education in schools, the research on science shadow education in academia is rare, and cannot provide empirical evidence to assess how science shadow education affects the performance of young people's scientific literacy, which in turn cannot provide a reliable reference for government intervention. Therefore, it is urgent to explore the impact of science shadowing on adolescents' scientific literacy in China and South Korea, which are representative East Asian countries where science shadowing is particularly prevalent, and it is socially important to study the impact of science shadowing on adolescents' scientific literacy as an important indicator of the effectiveness of the time spent on science shadowing.

The East Asian social circle, represented by China and South Korea, has inherited the Confucian official-oriented value system of "learning and excellence", which continues to this day. The shadow education policy introduced by the Korean government has also undergone a transformation from prohibition to rationalization during the half-century-long political game. In the 1970s, in order to control the overheating of entrance examinations, the Korean government began to implement a policy of "equalization" of education, whereby school curricula were based on the standards of intermediate students and extracurricular tutoring became popular among students aiming to attend prestigious universities. In the 1980s, then-President Chun Doo-hwan enacted the College Act, which banned all extracurricular tutoring. The ban was hailed by much of the Korean public at the time, but lasted only a decade or so before the government allowed college students to work as private tutors and licensed some extracurricular training institutions. When President Kim Dae-jung came to power in the new century and repealed the "equalization" of education, after-school institutions expanded again, sweeping the country. In 2003, civilian President Roh Moo-hyun took over the reins of education reform, proposing a "three no's policy" to avoid class solidification, but it collapsed under the pressure of public opinion dominated by the chaebol clique. Since then, Lee

Myung-bak, Moon Jae-in, and Yoon Seok-yeol, who have been in charge of the Cheong Wa Dae administration, have also made changes to ease extracurricular tuition, but with little success. The term "four when five fall" is widely circulated in the circle of Korean students, that is, four hours of sleep a day, you can get into the university, if you sleep five hours, you have to fail the exams. SKY University (i.e., Seoul National University, Goryeo University and Yonsei University), represented by a group of school valves monopolize the high-end social circle of South Korea, whether it's for the future of an individual, or the continuation of the family's honor, to get into a prestigious university. Whether for personal future, or to continue the honor of the family, to get into a famous school is the only "pass" to win the secular success of the general public.

Objectively speaking, China's current "double-reducing" policy is somewhat similar to South Korea's ban policy in the past, with the aim of overcoming the risk of elitism in education under the logic of the market, thus easing the latent class contradiction under the logic of this logic. 2015, the Ministry of Education issued what is known as the most stringent "ban on compensated tuition" - "Strictly prohibiting primary and secondary schools and primary and secondary school teachers from compensated tuition" in the past. In 2015, the Ministry of Education of China (2015) issued what has been described as the toughest "ban on compensated tuition" in history, the Provisions on Strictly Prohibiting Elementary and Middle Schools and In-service Elementary and Middle School Teachers from Paying for Compensated Tuition.2021 In July of 2012, the General Office of the Central Committee of the Communist Party of China (CPC) and the General Office of the State Council issued the Opinions on Further Reducing the Homework Burden of Compulsory Education and the Burden of Out-of-School Training, which explicitly proposed insisting on In November 2022, the General Office of the Ministry of Education and twelve other departments jointly issued the Opinions on Further Strengthening the Work of Preventing and Governing the Invisible Variation of Discipline-Based Training, which re-emphasized the risk of the marketization of shadow education and put forward corresponding defensive measures. The differences in policies and attitudes towards shadow education in different countries reflect to some extent whether people care about or recognize its influence on students' academic achievements. Therefore, it is of great practical significance to explore the potential problems and social impacts of science shadow education in China's basic education stage, if we can explore the impacts of shadow education on the scientific literacy of young people in the context of countries with similar backgrounds and origins of shadow education. Therefore, the present

study attempts to investigate the influence of shadow education time on adolescents' scientific literacy through an empirical comparison between China and South Korea.

Generally speaking, based on the results of literature analysis, this study initially establishes a system of factors influencing adolescents' scientific literacy, including the variables of time of science shadow education, scientific literacy and other related variables, etc. Relying on the PISA2018 database, the study adopts the method of multivariate linear regression analysis and constructs a model on the basis of full consideration of the endogenous factors to reveal the effects of the time of shadow education on the adolescents' scientific literacy in the context of different countries, and analyze the deep-seated reasons for the differences in the effects, so as to standardize the shadow education and provide a reference for the relevant policy reforms. We also analyze the deep-seated reasons for the differences in the effects, so as to standardize science shadow education and provide a reference basis for related policy reforms. Based on the data of PISA2018 China-Korea survey, this study tries to answer the following research questions.

1. is there a significant effect of science shadowing time on adolescent scientific literacy?

2. is there a significant difference in the effect of science shadow education time on the scientific literacy of Chinese and Korean adolescents?

3. Does science shadow education widen educational inequities?

2.Literature review

For the time being, the academic discussion on the impact of shadow education on students' academic achievement and even educational equity has not yet reached a consensus. Based on the PISA2012 survey data from Shanghai, Hong Kong, Japan and South Korea, Hu et al. (2017) used multilayer linear model and weighted propensity score matching method, and found that the shadow education time of Japanese and South Korean students had a significant positive effect on their academic achievement, while Hong Kong and Shanghai, China, showed a significant negative effect, and the shadow education time had a higher degree of influence on Japanese and South Korean students than on Chinese students, and the analysis results also showed that shadow education could reduce the differences in academic achievement of students under the influence of family capital. In addition, the results of the analysis also show that shadow education can reduce the differences in students' academic achievement under the influence of family capital. Xue and Shi (2022) argued that shadow education can enhance students' academic achievement but is not conducive to educational equity. Based on the data of China Education Panel Survey (CEPS) and using structural

equation modeling, the results of this study showed that students with high family capital are more willing and likely to receive shadow education, and shadow education also has a negative impact on their academic achievement. Smyth (2009) also explored the relationship between shadow education and students' academic achievement from the perspective of social class, and found that students from middle-class families in Ireland were the main participants in shadow education, but shadow education did not have a positive effect on students' academic achievement. education did not have a significant positive effect on students' academic achievement. The research results of Li et al. (2016) show that the impact of shadow education on students' academic achievement is first increasing and then decreasing, in which the educational expectations of families and adolescents are the key variables affecting the turn of the trend. Generally speaking, the current academic research on the impact of shadow education on students' academic achievement and even educational equity provides a scientific methodological reference for this study, but the controversy over whether shadow education has a significant impact on adolescents' academic achievement and educational equity needs to be debated according to the results of the analysis of specific issues.

In addition, the existing research results on adolescent scientific literacy focus on the current situation and cultivation paths. Based on the PISA2018 survey data from four provinces and cities in China (i.e., Beijing, Shanghai, Jiangsu, and Zhejiang), Chen (2022) constructed a multilayered mixed logistic model to analyze the effects of family scientific capital and scientific literacy on adolescents' STEM career aspirations and the paths of the effects, and found that family scientific capital can be effectively transmitted by family material resources, educational resources, and cultural capital only when adolescents have high scientific literacy or relative advantages in mathematics. It is found that family science capital can only be effectively transmitted by the family's material, educational and cultural capital if the adolescents have high scientific literacy or relative advantage in mathematics. Wei and Lin (2022) discussed the performance of adolescents' scientific literacy in the official high school chemistry curriculum (SHSCC) promulgated by the Ministry of Education of China in 2018 from the perspective of the three visions of scientific literacy in the context of the discipline of chemistry. You, Park, & Delgado (2021) based on the PISA2015 curriculum of U.S. secondary schools, discussed the impacts and pathways of family science capital on STEM career aspirations. PISA2015 survey data from U.S. secondary schools, a multivariate three-level modeling approach was used to investigate the relationship between two measures of scientific literacy (i.e., content knowledge and epistemological knowledge) and school

characteristics, and the results indicated that there were predictions of school size, teaching experience, professionalism, pedagogical methods, and instructional quality on the academic performance of all students. Kim (2021) found that extracurricular tutoring to strengthen students' subject knowledge, test-taking skills, and to address learning difficulties plays an important role in enhancing students' academic achievement. Based on the PISA2015 survey data from China and South Korea, Zhan et al. (2021) constructed a multiple linear regression equation model, which showed that science shadowing had a significant negative impact on the scientific literacy of both Chinese and Korean students. On the whole, the research on the relationship between shadow education time and youth scientific literacy has not been widely noticed by academics, and the question of how shadow education affects students' academic achievement has not been concluded, especially the empirical research on shadow education time in China is obviously insufficient to provide a reliable example for assessing the impact of science shadow education time on youth scientific literacy, and to provide a reliable example for assessing the impact of science shadow education time on youth scientific literacy, and for assessing the impact of science shadow education time on youth scientific literacy in China. It cannot provide a reliable example for assessing the impact of science shadow education time input on adolescents' scientific literacy, nor can it find a definite solution for the future direction of the "double reduction" policy. At the same time, there is a relative lack of discussion of the differences between countries with similar backgrounds and origins in science shadowing.

Therefore, based on the consideration of the value of topic selection, technical path, and potential mining space, this study relies on the relevant assessment data of PISA2018 Chinese and Korean students' questionnaires and schools' questionnaires, and establishes a multivariable linear regression model (multivariable linear regression model) with full consideration of endogenous factors, and investigates the effect of shadow education time on scientific literacy of Chinese and Korean adolescents based on different national political backgrounds and East Asian societies, and the influence of shadow education time on scientific literacy based on different national political backgrounds, East Asian societies, and East Asian societies. The multivariable linear regression model (MLRM) and ordinary least squares (OLS) were used to investigate the effect of shadow education time on the scientific literacy of Chinese and Korean youths, and to explain the reasons behind the differences in the effect based on the political backgrounds of the different countries and the cultural origins of the East Asian social circles.

3.Methodology

3.1 Data sources

The Program for International Student Assessment (PISA) is a policy-driven research program that tests and evaluates the reading, math, and science skills of 15-year-olds, and collects detailed background information on the target population through questionnaires for students, teachers, and schools in order to provide policy recommendations for future education reform and development. The program is designed to collect detailed background information on the target population in three categories of questionnaires: students, teachers, and schools, in order to provide policy recommendations for future education reform and development. Since 2000, PISA surveys have covered more than 90 countries and economies worldwide, involving nearly 30 million school students, and the student questionnaires in PISA surveys have covered questions about students' study time, which mainly involves regular classroom time in school, self-study time in and out of school, private tutorial time outside school, and one-on-one private tutoring time. All the data in this study were obtained from the official website of the Organization for Economic Cooperation and Development (OECD), and belong to the latest collection of PISA public data, i.e., selected from the PISA2018 database of China (Beijing Municipality, Shanghai Municipality, Jiangsu Province, etc.), In other words, 3337 samples from China (Beijing, Shanghai, Jiangsu, and Zhejiang provinces) and 2742 samples from South Korea were selected from the PISA2018 database for comparative analysis.

3.2 Design variables

According to the findings of existing studies, the factors affecting adolescents' academic performance mainly include three levels: individual, school and family. Therefore, in this study, the independent variables affecting adolescents' scientific literacy were selected mainly from the above three levels, combined with the actual variables covered in the PISA2018 database.

The selection of variables at the individual level of adolescents was mainly based on study time. Depending on the nature of the time, learning time was divided into classroom learning time, self-study time outside the classroom and extracurricular tuition time. Classroom study time is defined as the length of each lesson multiplied by the number of lessons; extracurricular self-study time is defined as all the time that adolescents spend on

self-study outside the classroom except for tutorials, e.g., writing homework; and extracurricular tutoring time is defined as the time that students spend on private tutoring outside the school. All of the above time is measured in hours and the length of time is one week. In addition to learning time, learning ability is also an important variable that affects adolescents' scientific literacy, such as learning efficiency and learning initiative, but unfortunately, the PISA2018 database does not collect such variables. Therefore, it is impossible to observe the correlation between adolescents' learning ability and tutoring time, and then it may lead to bias in estimation. To solve this problem, this study introduced other variables as proxy variables. In addition, gender difference is also an important variable to be considered.

In the selection of variables at the school level, this study mainly considered six factors: school size, school location, school nature, class size, computers per capita in the school, and student-teacher ratio. Among them, school size, number of computers per capita and student-teacher ratio are continuous variables, while school location, school nature and class size are dummy variables.

For the selection of variables at the family level, this study mainly considers the family socio-economic status index (economic, social and cultural status, abbreviated as ESCS) in the PISA2018 database, which is an index calculated by the project implementer after counting a series of factors such as family income, parents' education level, and so on. which is an important variable influencing the scientific literacy of young people at the family level

3.3 Analysis model

3.3.1 Basic model

In order to deeply analyze the factors affecting adolescents' scientific literacy, this study established a multivariable linear regression model, and used the ordinary least squares (OLS) method to estimate the parameters of the influence of each factor on scientific literacy. The basic model is shown in equation 1.

$$Spv1=\beta_0+\beta_1 schloca+\beta_3 puborpri+\beta_4 schsca+\beta_5 comstu+\beta_6 stutea+\beta_7 gender+\beta_8 ESCS+\beta_9 sclalearn+\beta_{10} sclalearn^2+\beta_{11} spri+\beta_{12} spri^2+\beta_{13} saftersch+\beta_{14} saftersch^2+\beta_{15} accumutime+u①$$

represents class size >30; puborpri refers to the nature of the school is public or private, taking the value of 0 represents the public school, taking the value of 1 represents the private

school; schsca refers to the size of the school, measured in terms of the total number of students in the school; comstu refers to the number of computers per capita in the school; stutea refers to the ratio of students to teachers; gender refers to the sex of the adolescents, taking the value of 0 for girls and 1 for boys; gender refers to the gender of the youth, taking the value of 0 for girls and 1 for boys. gender refers to the gender of the adolescent, with girls taking the value of 0 and boys taking the value of 1; ESCS index reflects the socio-economic status of the adolescent's family, and is weighted to take into account the parents' education level, occupational status, and the number of representative objects owned by the family; sclalearn and sclalearn ^{2} refer to the time spent on science classrooms in school and its squared term; and spri and spri ^{2} refer to the time spent by adolescents on science subjects in school and its squared term. refer to the after-school self-study time spent by adolescents on science subjects and its square term, including time spent on homework, other self-study time, etc.; and saftersch and saftersch ^{2} refer to the out-of-school remedial time spent by adolescents on science subjects and its square term. All of the above times are measured in hours, and the length of the measure is one week.

The last variable in equation 1, accumutime, measures the cumulative time spent by adolescents in extracurricular tutoring, measured in weeks. This variable can be used as a proxy for some intrinsic, unobservable factors that affect adolescents' scientific literacy, thus solving the endogeneity problem in the measurement model. Those students with lower levels of scientific literacy were more likely to participate in remediation than those with superior scientific literacy. However, the student's prior academic performance in science is unobservable, so it is reasonable to assume that if he has routinized tutoring during his academic career, this behavior will largely influence his current choice of tutoring time, and this variable is included to control for the student's own influence on tutoring time. However, it is worth noting that only this one variable may not fully solve the endogeneity problem of the model, such as learning ability will affect the time students spend on learning, which is unobservable, and thus the slope coefficient may still be biased. This issue of how to control for adolescents' learning ability will be continued in the extended model.

3.3.2 The extended model after controlling learning ability

Since there is no indicator of individual adolescents' learning ability given in the PISA2018 database, this study will control for it by finding proxy variables. It is well known that it is a very common phenomenon in China and Korea that the level and quality of a school often reflect the level of learning of the students in that school. Although it cannot be ruled out that there are low-level students in high-level schools and high-level students in

low-level schools, generally speaking, the learning ability of students in high-level schools is higher than that of students in low-level schools. The reasons for this are as follows: First, high-level schools and students with high learning ability promote each other, forming a virtuous circle in the process of school development and personal growth. Secondly, high-level schools generally have a higher threshold for selecting students, so that only students with higher learning ability can enter the school. Therefore, school level is used as a proxy variable for students' learning ability in this study. It is worth noting that there are many variables that can reflect the level of the school, but the level of student ability is the most representative. Therefore, in this study, the scores of all students who participated in the scientific literacy test in the student's school were summed up and averaged, and the average was used as a measure of the level of the school. On the basis of regression equation ①, proxy variables were added to indicate the level of students' learning ability to control the endogeneity of the model, as shown in equation ②.

$$Spv1=\beta_0+\beta_1 schloca+\beta_3 puborpri+\beta_4 schsca+\beta_5 comstu+\beta_6 stutea+\beta_7 gender+\beta_8 ESCS+\beta_9 sclalearn+\beta_{10} sclalearn^2+\beta_{11} spri+\beta_{12} spri^2+\beta_{13} saftersch+\beta_{14} saftersch^2+\beta_{15} accumutime+\beta_{16} proxy + u \quad ②$$

Since the proxy variable is highly correlated with the school level, using it as a control variable may result in multicollinearity with other school-level control variables in the regression equation, leading to changes in the regression coefficients of some variables in terms of their joint significance, but in order to make the coefficients of the variable explaining the time spent on remedial work more accurate, the changes in the significance of the other control variables are negligible.

3.3.3 The extended model after adding tutorial content

In the PISA2018 test questions, in addition to focusing on the number of hours of tutoring that adolescents spend on each subject, the study also focuses on the differences in the content of the tutoring they receive in tutoring classes. Therefore, this study further cross-checked the data investigating the content of science tutorials in PISA2018 with the data on the number of hours spent on tutorials to investigate how the number of hours spent on tutorials affects adolescents' scientific literacy when there are variations in the content of science tutorials, and the variable selected was whether the content of science tutorials included new content outside of the regular science curriculum in schools.

To this end, a new dummy variable, content, was set to represent whether or not the science remediation content included new content outside of the regular school science curriculum, with values of 0 and 1 meaning that the science remediation content included new content and did not include new content, respectively. As shown in equation (3), the coefficient in front of the saftersch variable in equation (1), multiplied by content as a cross term, indicates how the change in the duration of remediation affects adolescents' scientific literacy when the content of science remediation includes new content outside the regular science curriculum in school.

$$Spv1=\beta_0+\beta_1 schloca+\beta_3 puborpri+\beta_4 schsca+\beta_5 comstu+\beta_6 stutea+\beta_7 gender+\beta_8 ESCS+\beta_9 sclalearn+\beta_{10} sclalearn^2+\beta_{11} spri+\beta_{12} spri^2+\beta_{13} saftersch*scontent+\beta_{14} accumutime+u \quad ③$$

4.Results

4.1 Descriptive statistical results

In this study, the survey samples of China (Beijing, Shanghai, Jiangsu, Zhejiang, etc.) and South Korea were selected from the PISA2018 database, and after removing the missing values and singular values, 3337 students from China (Beijing, Shanghai, Jiangsu, Zhejiang, etc.) and 2742 students from South Korea were extracted in terms of scientific literacy as well as other variables, which generally satisfied the large-sample nature. The overall values of these two groups of students satisfy the nature of large samples.

From the descriptive statistics of the relevant variables in Tables 1 and 2, Chinese students' scores on scientific literacy were higher than those of Korean students at both the upper and lower limits, but the mean scores were slightly lower than those of Korean students. To some extent, there are stronger individual differences in the performance of Chinese students in scientific literacy than that of Korean students. In terms of student-level variables, Chinese students spent much more time in the in-school science classroom than Korean students, the same amount of time for self-study, and slightly less time for extracurricular tutoring than Korean students. In the case of extracurricular tutorials involving new content outside the regular school classroom, China is higher than Korea. In terms of school-level variables, China has larger classrooms than Korea. In terms of family-level variables, Chinese students have a significantly lower family SES than Korean students.

Fig. 1. Descriptive statistics of Chinese related variables

variable name	observations	minimum value	maximum value	average value	standard value
spv1	3337.00	180.49	832.27	521.97	100.13
schloca	3337.00	0.00	1.00	0.88	0.32
clasca	3337.00	0.00	1.00	0.88	0.33
puborpri	3337.00	0.00	1.00	0.10	0.29
schsca	3337.00	48.00	11071.00	1893.94	1822.76
comstu	3337.00	0.00	3.88	0.43	0.41
stutea	3337.00	2.53	100.00	12.04	6.50
gender	3337.00	0.00	1.00	0.52	0.50
ESCS	3337.00	-4.35	3.04	-0.86	1.13
sclalearn	3337.00	0.00	40.00	5.26	3.17
spri	3337.00	0.00	30.00	6.43	5.79
saftersch	3337.00	1.00	20.00	3.96	3.48
scontent	3337.00	0.00	1.00	0.50	0.50

Fig. 2. Descriptive statistics of Korean related variables

variable name	observations	minimum value	maximum value	average value	standard value
spv1	2742.00	142.98	809.73	526.53	92.47
schloca	2742.00	0.00	1.00	0.99	0.11
clasca	2742.00	0.00	1.00	0.41	0.50
puborpri	2742.00	0.00	1.00	0.20	0.40
schsca	2742.00	35.00	1600.00	804.97	288.52
comstu	2742.00	0.00	3.30	0.45	0.59
stustea	2742.00	1.00	27.35	13.59	3.41
gender	2742.00	0.00	1.00	0.55	0.50
ESCS	2742.00	-2.16	3.38	0.15	0.75
sclalearn	2742.00	0.00	18.00	2.66	1.23
spri	2742.00	5.00	30.00	7.12	4.59
saftersch	2742.00	5.00	30.00	17.40	7.60
scontent	2742.00	0.00	1.00	0.14	0.34

4.2 Multivariable linear regression results

The regression results of Equation 1, Equation 2, and Equation 3, which reflect the effects of extracurricular tutoring time on the scientific literacy of Chinese and Korean youths, are shown in Tables 3 and 4, and it is found that, while the control variables of the two basic models are exactly the same, the results of the saftersch term analysis are significantly different. In China, there is a negative linear relationship between extracurricular tutoring time and students' scientific literacy, i.e., as extracurricular tutoring time increases, students' scientific literacy tends to decrease. In Korea, there is a positive linear correlation between extracurricular tutoring time and students' scientific literacy, i.e., as extracurricular tutoring time increases, students' scientific literacy increases accordingly. China and South Korea are typical representatives of the "internalization" of education in East Asia, but the results of Chinese students' tutoring do not conform to the positioning of shadow education - cultivating excellence and excelling - in the general impression of society. The reason for this deviation

from reality may be related to the fact that endogenous factors such as students' learning ability cannot be observed in the basic model, which biases the regression results to a certain extent.

Fig. 3. The regression results of the impact of tutoring time on scientific literacy in China

explanatory variable	basic model	after controlling learning ability	after adding tutorial content
schloca	22.091(0.000)***	-0.975(0.788)	22.271(0.000)***
clasca	19.930(0.000)***	1.872(0.622)	19.753(0.000)***
puborpri	10.714(0.053)*	-3.518(0.406)	10.326(0.062)*
schsca	0.006(0.000)***	0.001(0.103)	0.006(0.000)***
comstu	12.267(0.002)***	4.960(0.096)*	11.934(0.002)***
stutea	-1.485(0.000)***	0.206(0.368)	-1.501(0.000)***
gender	1.566(0.589)	8.509(0.000)***	2.033(0.484)
ESCS	37.407(0.000)***	6.248(0.000)***	37.739(0.000)***
sclalearn	11.739(0.000)***	6.093(0.000)***	11.842(0.000)***
sclalearn ^{2}	-0.490(0.000)***	-0.227(0.000)***	-0.501(0.000)***
spri	1.701(0.009)***	1.206(0.016)**	1.388(0.030)**
spri ^{2}	-0.077(0.004)***	-0.060(0.004)***	-0.073(0.007)***
saftersch	-2.480(0.030)**	-1.436(0.099)*	—
saftersch ^{2}	0.046(0.510)	0.028(0.599)	—
saftersch*scontent	—	—	-1.498(0.001)***
accumutime	1.350(0.000)***	0.143(0.423)	1.316(0.000)***
proxy	—	0.916(0.000)***	—
observations	3337	3337	3337
R^2	0.311	0.599	0.310

*indicates that sig<0.1;**indicates that sig<0.05;***indicates that sig<0.01.

Fig. 4. The regression results of the impact of tutoring time on scientific literacy in Korea

explanatory variable	basic model	after controlling learning ability	after adding tutorial content
schloca	-23.403(0.121)	-1.211(0.930)	-30.516(0.046)**
clasca	14.532(0.000)***	0.475(0.879)	15.799(0.000)***
puborpri	9.915(0.041)**	-0.966(0.827)	10.205(0.038)***
schsca	0.021(0.002)***	-0.001(0.916)	0.026(0.000)***
comstu	-17.017(0.000)***	4.060(0.184)	-20.170(0.000)***
stutea	-0.640(0.370)	0.159(0.807)	-0.806(0.265)
gender	13.455(0.000)***	8.538(0.004)***	10.646(0.001)***
ESCS	21.208(0.000)***	10.629(0.000)***	26.075(0.000)***
sclalearn	12.674(0.000)***	9.380(0.000)***	13.986(0.000)***
sclalearn ^{2}	0.072(0.767)	-0.567(0.011)**	0.048(0.846)
spri	-3.109(0.022)**	-3.728(0.002)***	-2.286(0.095)*
spri ^{2}	0.028(0.567)	0.061(0.167)	0.012(0.804)
saftersch	3.696(0.000)***	2.381(0.008)***	—
saftersch ^{2}	-0.048(0.079)*	-0.032(0.202)	—
saftersch*scontent	—	—	0.470(0.034)**
accumutime	0.622(0.025)**	-0.094(0.711)	0.651(0.021)**
proxy	—	0.867(0.000)***	—
observations	2742	2742	2742
R^2	0.195	0.333	0.172

*indicates that sig<0.1;**indicates that sig<0.05;***indicates that sig<0.01.

After the introduction of proxy variables to control students' learning ability, it was found that the differences in the saftersch term analysis results were significantly reduced when the control variables of the two new models were identical. In China, students' scientific literacy performance decreased with the increase of extracurricular tutoring time, but the negative effect of tutoring was weakened compared with the basic model. In Korea, students' scientific

literacy is still significantly positively related to the amount of extracurricular tutoring time, which suggests that shadow education does have a large positive effect in Korea. In addition, compared with the basic model, the introduction of proxy variables also weakened the significance of the control variables at the school level.

After adding tutoring content as a cross-section term, it was found that there were some differences in the scientific literacy performance of Chinese and Korean students in Model 3, but the differences were significantly lower compared with the regression results of the previous two models. In China, when extracurricular science tutoring covers new content outside the regular school classroom, the duration of tutoring is still negatively correlated with scientific literacy, and the negative effect has increased compared with that in model 2. In Korea, when extracurricular science tutoring covered new content outside the regular school classroom, students' scientific literacy performance increased with the increase of extracurricular tutoring time, but the positive effect was weakened compared with model 2. This suggests that the addition of new extracurricular content in remedial programs has a limited effect on enhancing students' scientific literacy, and if the new content is biased, strange, or difficult, the formality of the remedial program may increase students' academic pressure. However, in the current situation, shadow education is recognized and understood as a tool for students to compete with their peers, and the talents it creates are at risk of being questioned whether they are truly "scientifically literate," thus falling into the trap of achieving excellence through training. In addition, data from China and Korea show that science classroom learning has an obvious positive effect on students' scientific literacy performance, but there is a tendency of increasing and then decreasing in both countries, which indicates that too much learning time also has a negative effect on students' scientific literacy performance.

Finally, since the subtraction of dummy variables is meaningless, this study subtracted continuous variables such as scientific literacy and time spent on science tutoring of Chinese and Korean students sequentially to obtain a cumulative total of 2,742 data sets. Considering that the third model mainly involves content dummy variables, the regression analysis of the third model was not conducted. The results of the regression analysis of the difference in performance between China and Korea are shown in Table 5. From the descriptive statistics in the previous section, it can be seen that the upper and lower scores of Chinese students' scientific literacy are higher than those of Korean students, but the mean scores are slightly lower than those of Korean students. However, the regression results of the differences indicate that the more time Chinese students spent on extracurricular tutoring in science than

Korean students, the lower the likelihood that Chinese students' performance in scientific literacy was higher than that of Korean students. This result also reflects that the positive effect of extracurricular science tutoring on students is relatively limited.

Fig. 5. The regression results of the impact of tutoring time on scientific literacy in China

explanatory variable	basic model	after controlling learning ability
Dschsca	-0.001(0.000)***	-0.001(0.001)***
Δ comstu	-4.546(0.000)***	-4.967(0.000)***
Δ stute	0.210(0.001)***	0.180(0.006)***
Δ ESCS	1.941(0.000)***	1.362(0.000)***
Δ sclalearn	-0.866(0.005)***	-0.729(0.018)**
Δ sclalearn ^{2}	0.032(0.136)	0.023(0.293)
Δ spri	-0.343(0.029)**	-0.308(0.049)**
Δ spri ^{2}	0.005(0.387)	0.004(0.474)
Δ sjuicesch	0.761(0.000)***	0.756(0.000)***
Δ aftersch ^{2}	-0.006(0.203)	-0.006(0.214)
Daccumutime	-0.009(0.848)	0.012(0.798)
Δ proxy	—	-0.030(0.000)***
observations	2742	2742
R^2	0.101	0.108

*indicates that sig<0.1;**indicates that sig<0.05;***indicates that sig<0.01.

4.3 Results of the investigation on the problem of science extracurricular tutoring

In order to understand the reasons for the negative effect of extracurricular tutoring in science on students' performance in scientific literacy, this study specifically analyzed the data from two questions, EC154 and EC163, in the PISA2018 student questionnaire.

From the responses of EC154, the statistical results after excluding invalid responses show that 50.1% of Chinese students and 86.3% of Korean students participated in extracurricular tutoring in science, which involves the content of the regular school curriculum, and extracurricular tutoring as a secondary processing of the content of the classroom at school, and the increase in the time of the tutoring may cause students to be tired and bored, which may lead to the ineffectiveness of tutoring or even a negative effect. Negative effect.

EC163 aims to understand why students choose to continue studying before and after school, and the survey data show that 58.6% of Chinese students and 74.7% of Korean students participate in tutoring to prepare for exams, and this kind of science tutoring for exams can hardly contribute to the real improvement of students' scientific literacy. Many students participate in tutoring involuntarily. 59.8% of Chinese students and 42.3% of Korean students are influenced by peer pressure and need tutoring to relieve mental anxiety; 56.2% of Chinese students and 63.5% of Korean students are coerced by parental authority to enter tutoring classes, which makes it difficult to produce satisfactory results. In addition, 30.9% of Korean students participated in extracurricular science tutoring out of personal interest, while only 18.4% of Chinese students did so, which is a possible reason for the positive effect of

extracurricular science tutoring among Korean students and the negative effect of extracurricular science tutoring among Chinese students.

5.Discussion

5.1 Significant effect of private supplementary tutoring Time on adolescents' scientific literacy in science education

Among the control variables selected from the three levels of individuals, families and schools in this study, except for a few variables that do not have a significant impact on adolescents' scientific literacy, the main variables such as classroom learning time and extracurricular tutoring time have a significant impact on adolescents' scientific literacy, and the related effects are basically in line with the generalization of the expectations. "Time is an important input factor in the production process of education (Shen, 2014). In East Asian societies, "time" is reflected in students' academic problems, usually manifested in the social "diploma mania", people attach great importance to education, investing a high amount of money, time, energy, and then construct a "high performance education system" achievement. High-performance education system" achievement, shadow education can be sprouted. However, the "gas pedals" behind this logic of work - instrumentalism and training - hide the "growth without development" and "present without future" concepts. However, the "accelerators" behind this logic of work - instrumentalism and trainerism - hide the risks of "growth without development" and "present without future" in the cultivation of human resources, which makes the "existence is justified" of shadow education questioned.

However, the significant influence of shadow education time in East Asian societies represented by China and South Korea is closely related to Confucianism, which has been the cultural lineage of the region for thousands of years (Wu & Hua, 2022). The superimposition of the concepts of "learning and excellence" and "education for all" conveys an important cultural metaphor, i.e., as long as one strives to study, one can move up the social ladder by virtue of one's talent and ability, regardless of one's background. In Japan and Korea, the expression "to make a name for oneself" and "to make a name for oneself" is also common (Liu & Meng, 2013). Confucian educational values are linked to the system of selecting government officials, creating a tendency to move up the social ladder based on competence and fairness of opportunity. In the path of "class advancement", Confucianism emphasizes sincerity and diligence, aiming to cultivate a focused and self-controlling character among the scholars, and the phrase "Heaven's way rewards diligence" has been widely praised in East Asian societies (Hou & Tang, 2016). Under the influence of the moral education thinking of

"hard work wins", the "rebellious spirit" of the underclass scholars in East Asian societies was constantly stimulated, and the "noble sons of the humble family" gained high academic achievements, cracking the "participation of education in class reproduction". The cultural ideal of "education participating in class reproduction" was also established (Zhang & Zhu, 2018).

Of course, the realization of this ideal is never easy, "ten years of hard work" has accordingly become a true reflection of the East Asian readers. Diligent East Asian readers in the pursuit of academic excellence in the road, not to be fixed in the school of preaching and teaching, but also elsewhere in the practice of "learning and excellence". As early as in the Han Dynasty, too students are keen to learn from famous teachers outside the school, the Confucian masters often set up their own "fine house", "fine hut", open the door to teach students. Jin Dynasty, private schools are quite developed, famous Confucian polytechnic lectures, often hundreds or thousands of students. Song Dynasty, White Deer Cave, Stone Drum, Yingtianfu, Yuelu four academies as the representative of the civil education institutions, easing the social crisis brought about by the downturn of the official school. The investment of time in shadow education has found the historical basis of "existence is reasonable" in the repeated practical tests, and nowadays, the expansion of shadow education has added a lot of rational explanations of modernity. As the process of universalization of higher education accelerates, there is a massive expansion in the number of new students enrolled and a growing differentiation between institutions (Bray, 2020). The rise of shadow education has been fueled by the intense competition among candidates "crossing the log bridge with thousands of horses" around the dominant universities. This competitive pressure and anxiety have moved forward with the wave of marketization of education, permeating different subjects at the basic education level. In order to gain a comparative advantage in the competition for quality educational resources, the money, time, and energy that students invest in shadow education deepens as the intensity of peer competition increases (Zhu, 2013).

5.2 Significant differences in the effects of private supplementary tutoring time on scientific literacy of Chinese and Korean Youth

The main question explored in this study, i.e., the effect of science shadowing time on adolescents' scientific literacy, after fully considering the endogenous factors, the results of the regression model showed that extracurricular tutoring time showed a significant negative effect on Chinese adolescents' scientific literacy, while it showed a significant positive effect on Korean students. This significant difference may be related to the different economic models of China and Korea.

As we all know, Samsung, Hyundai as the leader of the chaebol group in control of South Korea's economic lifeblood, the best universities, the most famous large enterprises, the most decent social circle gathered in Seoul "pyramid" top of the family in the hands of celebrities, which means that the upward mobility of the ordinary people narrowed the channel. According to a report, the 64 chaebol corporations accounted for 84.3% of Korea's nominal GDP but only created 11.4% of the jobs in 2019 (CXO Institute, 2020). This elitist hiring mechanism especially favors students from prestigious schools, and ordinary people who aspire to excel have to squeeze into Seoul as soon as they are born and roll through schools, cram schools, and SKY University until they get a ticket to a big company. The study of Zhao and Li (2012) also shows that alumni relationship has a strong linking function in Korean society, which builds a strong network of contacts and nepotism in a specific class environment, and provides an opportunity for individuals to build a strong network of contacts and nepotism in a specific class environment. It builds a strong network of contacts and nepotism in specific class environments and brings substantial benefits for personal development.

As a result, Korean parents are investing a great deal of money, time and energy in education at all costs. In order to take care of their children's lives and education, many Korean women give up their jobs after marriage and become housewives, while men take on the responsibility of earning money to support their families, providing strong financial support for the high investment in their children's education (Jang & Merriam, 2004). According to the data released by Statistics Korea in 2003, the average monthly total expenditure of the top 20% of households with children aged 13～18 in the first quarter of this year was 6.53 million won, of which 1.143 million won was spent on extracurricular tutoring, 636,000 won on food and drink, and 539,000 won on housing, utilities, meaning that the total amount of the family's monthly consumption on food and drink is comparable to that of the children's tutoring fees (Jang & Merriam, 2004). This means the total amount spent by the whole family on food and living in a month is comparable to the cost of tutoring for their children (Bray, 2013). It can be said that most Korean families are a collaborative unit centered on education, where the success of the children's education is the success of the whole family, and the children see "studying hard" as an effective emotional expression of filial piety. In order to be grateful for their parents' dedication and commitment, and to realize their self-expectation of being a member of a prestigious social class, Korean teenagers study around the clock, attending cram schools after finishing school every day, even on weekends and holidays (Seth, 2002).

Along with the "education boom" in Korea, extracurricular cram schools have completed a brutal reshuffle in the market economic competition of survival of the fittest, and those extracurricular cram schools, which have won a high reputation in Seoul's education circle, have eventually formed a systematic industry chain. The cram schools are scrambling to offer products that prepare students for special high schools such as foreign language high schools and science and technology high schools, as well as test-taking products that help students study ahead of time and study for college entrance exams. The "killer questions" are so common in Korea's college entrance exams that it is difficult for students to get good grades by relying only on textbook knowledge (Dong-A Ilbo, 2023). Remedial classes help them save time, where they can study intensively in a short period of time and efficiently solve the correct answers to the questions in the GCSE for a subject that is beyond the syllabus.

In China, however, public schools under government-run schools dominate the national basic education discourse. Unlike South Korea, where head capital is running around in the domestic basic education market, from the capital to the local provinces and municipalities, China's public schools often have excellent teachers and student sources, generally showing a structural balance between the government's "fairness" on the supply side and "efficiency" on the students' demand side. The overall structural balance between the government's supply-side "equity" and students' demand-side "efficiency". However, in contrast, shadow education is provided by a variety of providers, including educational institutions, one-on-one tutoring, private tutors, and so on (Bray, 2013). Especially in the field of science education, the phenomenon of part-time tutoring teachers is common and lacks professionalism, the teaching content has few thematic activities to stimulate students' scientific inquiry ability and interest in science learning, and the instrumentalized tutoring mode does not create added value outside of school science education (Bray, 2013). According to the black-and-white list of out-of-school tutoring organizations published by the Ministry of Education in 2018, the first phase of the capital city of Beijing investigated the number of out-of-school tutoring organizations at 12,681, of which 7,557 had problems with the irregularity of running schools at a rate as high as 59.59%. The break between the quality of school education and the environment of the tuition market is likely to be a major reason for the negative effect of shadow education time on the scientific literacy of Chinese youth.

In addition, compared with South Korea, China in the transition period of modernization, the peer pressure in the environment of huge population size also accumulates more obvious family education anxiety, and the authoritarianism from parents and the training of cram schools create irrational cramming chaos. Chen and Bai (2015) found that parents are affected

by peer pressure to choose extracurricular tutorials for their children, and this choice is often irrational to some extent. tutoring for their children, and this choice is often somewhat irrational. The concept of studying for the purpose of test-taking grows indefinitely, and students voluntarily or involuntarily participate in extracurricular tutorials, mastering the skills of high scores by repeating problems and over-studying, but numbly they do not really learn to learn, and deviate from the principle of healthy life, and there is no way to talk about the spirit of science and practice and innovation. Kuan (2018) found that participation in extracurricular tutorials may Chen Kuan (2021) also stated that the probability of participation in extracurricular tutoring is positively correlated with the degree of adolescents' emotional health. In this way, the influence of adolescents disordered psychological state on their academic achievement performance can be rationalized.

5.3 Private supplementary tutoring time in Science Education can widen educational inequities

The irrational phenomena attached to scientific shadow education profoundly reflect the specificity of educational needs, the complexity of educational contradictions and the social nature of educational problems, and directly point to many deep-seated doctrinal issues, such as educational fairness and balanced development, educational livelihood and services, and educational individuality and diversity (He, 2023). Education level is a key factor in determining future competitiveness, and the gap between the supply and demand of quality education resources makes parents, who are naturally anxious, unwilling to let their children lose at the starting line, which has given rise to a booming market of out-of-school training. Changes in the educational philosophy of the middle class have led to changes in society as a whole, as well as changes in low-income families, and the prevalence of "shadow education" is a typical manifestation of such changes in society as a whole (Bray, 2020). However, the investment of high-income families in shadow education is far from being comparable to that of low- and middle-income families, and the two are not on the same competitive track, with the former having the characteristics of high-end and internationalization. For the middle class, the investment in shadow education is an important strategy to avoid the crisis of class decline in future generations. For low-income families, shadow education investment is the main channel to expand the opportunity of upward mobility.

But while the prevalence of "shadow education" comes from a sense of crisis among parents, there is also a deeper external force - the inability of in-school education to fully meet the educational needs of students. It is for this reason that parents try to find compensation

from off-campus training organizations. For example, the compulsory schooling program, to a certain extent, only transfers the pressure of learning from the school to outside the school. This heavy reliance on out-of-school tutoring has, in fact, led to new educational injustices. Students' academic performance does not depend entirely on their own talents and efforts, but is closely related to the educational resources they have access to, and the social and cultural capital that their families can create (Kim & Lee, 2021).

It is worth mentioning that as this external force has regained the lead in the education reform process, the policy protection mechanism within the education system has been gradually failing. Looking back over the past half-century, the South Korean government's shadow education policy of "prohibition" and "compensation" has been exposed. In China, the "double-reducing" policy has explicitly ordered a series of measures such as strictly regulating the approval system of extracurricular tutorial institutions, providing after-school extended time services, and developing quality education, so as to do a good job of adding to the content of curricula and subtracting from the burden of teaching (Shi, Li & Chen, 2022). Indeed, the ultimate goal of the "double-reducing" policy is to restore the ecology of education and avoid test-oriented and short-sighted education (Liu, Luo, Li & Li, 2023). But in fact, as long as the social consensus of "scores determine everything" is not adjusted, parents' anxiety remains, students' pressure is not reduced, and families' burden remains heavy, it cannot be considered as a real reduction of the burden of education (Li, 2023). Therefore, in addition to reconstructing the internal policy mechanism of the education system, it may be more important to objectively understand the function of education evaluation and rationally analyze the results of education evaluation. In particular, when adapting policies based on the results of international education assessment, the representativeness of data and the limitations of research should be fully considered (Shu & Sheng, 2019). The final results of education quality assessment should be based on the measurement of learning efficiency, maximize the feedback effect of assessment on students' academic performance, and guide them to shift their attention from "more study time" to "quality study time".

6. Conclusion

The empirical findings of this study provide solid evidence for assessing the impact of time spent in and out of school on the academic achievement of adolescents in science subjects at the basic education level in East Asian societies. The study suggests that "time" is a key variable affecting the quality of knowledge production in both schooling and shadow education, and that efficient learning cannot be achieved without scientific and rational

learning time planning. The threshold of time control is not a simple and mechanical "subtraction", but also a precise positioning of the relationship between school science education and science shadow education. School science education should help students to master ontological and conditional knowledge, while science shadow education should provide more practical knowledge, so that science education inside and outside the classroom can articulate and interact with each other, so that students can continuously improve their core academic qualities and key competencies through social participation, and realize the "cultivation and enhancement effect" under the limited time for learning input. In addition, in response to the irrational shadow education behavior driven by parental authority and peer anxiety, the government needs to provide guidance in both a firm and a soft manner, conduct regular research on the industry environment of the education and training market, and timely disclose to the society the national research reports and latest information based on the evaluation and monitoring of big data, so as to let the parents and students objectively look at the marginal benefit of the time invested in the shadow education, and to reduce the group trust and dependence of the society. Finally, it is worth noting that in the modern era of pervasive technology, there is a strong connection between the external environment of society and the inner life of the individual. Individuals have been placed in an all-encompassing network where even the smallest actions are pushed to the forefront, even creating social illiteracy under strong peer competition and high pressure. So, it is important to recognize yourself. As an individual, you need to construct a relationship with yourself, others, and the world with a humble and non-attached mind, and gradually awaken and take action in the process of generating knowledge by accepting the outside world, exploring science, and discovering the truth.

Author contributions

CL and QT presented the main idea and wrote the first draft of the manuscript. CL interpreted the data and drafted the manuscript. PW reviewed the manuscript. QT revised the manuscript and finished the submission. All authors contributed to the article and approved the submitted version.

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