Influencing Factors of PISA Science Performance: a qualitative meta-analysis

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Abstract. This study takes a qualitative meta-analysis method to conduct a more comprehensive analysis and integration of 17 studies from 2009 to 2018. From the three dimensions of system, school and student, this paper summarizes the influencing factors of PISA scientific performance. Major findings include that most studies of the influencing factors of PISA scientific performance focus on the relationship between the variables of school level and student level and PISA science performance, especially the relationship between student level and PISA science performance. These findings may provide insights for researchers and educators into research trends in the influencing factors of PISA scientific performance.

Keywords: PISA, scientific achievements, influencing factors

INTRODUCTION

The program for international student assessment (PISA), which originated in 1997, is a triennial international test initiated by the organization for economic cooperation and development (OECD). It is aimed at 15 -year- old students who have nearly completed basic education. It assesses whether they have mastered the knowledge and skills required for survival in modern society and to what extent. Science, mathematics and reading are the three main assessment fields of PISA. International testing was first conducted in 2000 and has been held every three years since. And the assessment of problem-solving ability was added in 2003, and the assessment of financial literacy was added in 2012. In addition, in the Program for International Student Assessment of 2006, science was a major field of assessment.

Consistent with the previous survey results, many Asian regions, such as Singapore, China, Hong Kong, Taipei, Macau, Japan, South Korea and Vietnam, were still at the top of the ranking list in 2015 PISA. The top ten Western countries in the

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list were Finland, Canada and Estonia (Lau & Lam, 2017). The studies found the influencing factors of PISA performance are diverse, and the factors that influence PISA science performance have always been the focus of researchers.

LITERATIVE REVIEW

The influencing factors of science performance have always been a hot topic for researchers. For instance, Lin (Lin, Yen, Liang, Chiu, & Guo, 2016) explored the conceptual changing factors that affect most students' science learning process and learning outcomes by accessing the ERIC and using content analysis methods and came to the following conclusions: 1) balance the relationship between teaching intervention and personal characteristics; 2) reexamine the role of teachers and the epistemology of students; 3) strengthening the link between disciplines and teaching methods. Acar (Acar, Türkmen, & Bilgin, 2015), based on the regression analysis model, studied the impact of cognitive and motivational factors on science achievement of eighth-grade students in Turkey and gender differences on factors which significantly contributed significantly to the science achievement model. The study shows that girls outperform boys in science. In addition, based on the regression analysis model, as independent variables, the initial concept knowledge, scientific reasoning and the value of science can best help predict students' performance in science. The results also show that there is no difference between boys and girls in the initial concept knowledge and scientific reasoning, but there are differences in the practical value of science. Acosta (Acosta & Hsu, 2013) analyzed three variables i.e. family, school and student with an aim of helping the youth in New Zealand and promote their PISA science performance. The study shows that family socioeconomic status (SES), the motivation of young people to learn science and the general value of science are important factors of influencing students' science achievement. The study also shows that there is a statistically significant interaction between SES and the first generation of immigrant families, but no significant interaction between SES and the second generation of immigrant families. In addition, although parents' views on the universal value of science have a positive impact on students' science performance, their predictive power is relatively limited. Odom (Odom, Marszalek, Stoddard, & Wrobel, 2011) sampled 294 seventh-grade students who are enrolled in science-oriented schools across four different school districts and two charter schools and researched the relationship between the variables of students' attitudes towards science, student-centered teaching practices, computer use and traditional teaching practices and students' science performance based on the multiple regression analysis. The study shows that the attitudes towards science and student-centered teaching practices are both positively related to students' scientific achievement, and that student-centered teaching practices are positively related to the attitudes towards science, while computer use and students' scientific achievement are negatively related, and traditional teaching methods have less impact on students' scientific achievement.

In addition to the study of the influencing factors of scientific achievement, research on the influencing factors of PISA science performance has always been a topic for researchers. For instance, based on the structural equation model, Anil (Anil, 2011) carried out a study in Turkey and found that among the variables that can help predict and determine students' scientific achievement, the most important one is time, followed by the factor of environment, then by teaching, and a low positive correlation was identified between science performance and students' attitudes towards science. In the study of 10 regions with the best performance in PISA, Lau (Lau & Lam, 2017) explored the relationship between teaching practices and science performance based on hierarchical linear modeling and it was found that teaching factors such as teachers' guidance are positively correlated with science performance in all regions. Kubiatko (Kubiatko & Vlckova, 2010), based on secondary analysis, studied students in Czech and found that those with some knowledge in information and communication technology (ICT) had better science performance in PISA. In addition, compared with those students who are not involved in ICT activities and educational processes, students who are involved had higher scores. Up to now, there are many studies centering on the influencing factors of science performance in PISA, but there is no study that systematically describes the influencing factors of science performance in PISA.

RESEARCH METHODOLOGY

General background of research

By analyzing the literature on the influencing factors of science performance, we found that the research samples in the literature are relatively simple, and the research results are not very consistent. The use of PISA data to study the factors of affecting science performance solves the problems in previous research and makes the research more comprehensive. Moreover, much of the previous research adopted the method of literature review, while in this study we adopted the ideas of Hattie (Hattie, 2009) and used the qualitative meta-analysis method to analyze the literature collected, so as to systematically clarify and summarize the influencing factors of PISA science performance. Therefore, the research questions of this study are as follows:
(1) What is the research status of previous studies on PISA science literacy and the influencing factors (study design, publication time, country involved, variables, etc.)?
(2) What are the characteristics of the previous studies (data sources, data processing methods, etc.)?
(3) What are the specific research results of these studies?

Literature collection

First, we accessed the Web of Science database, focused on its core collection and entered the key terms PISA and science. The screening criteria at this stage are: 1) the title contains the key terms PISA and science; 2) the document type is article; 3) publication language is English; 4) the categories on the Web of Science are EDUCATION and EDUCATIONAL RESEARCH. At this stage, 38 articles were obtained. Then, at the second stage, the title, abstract or full text of the above-mentioned 38 articles were read and sorted again based on the following criteria: 1) the research objects include PISA science performance; 2) the research must involve the influencing factors of PISA science performance. At this stage, 18 articles were obtained. Then, at the third stage, the full text of the above 18 articles were carefully read, and the articles were further sorted according to the following criteria: the articles must be in consistency with our classification framework of the influencing factors of PISA science literacy. Therefore, the final number of valid articles is 17.

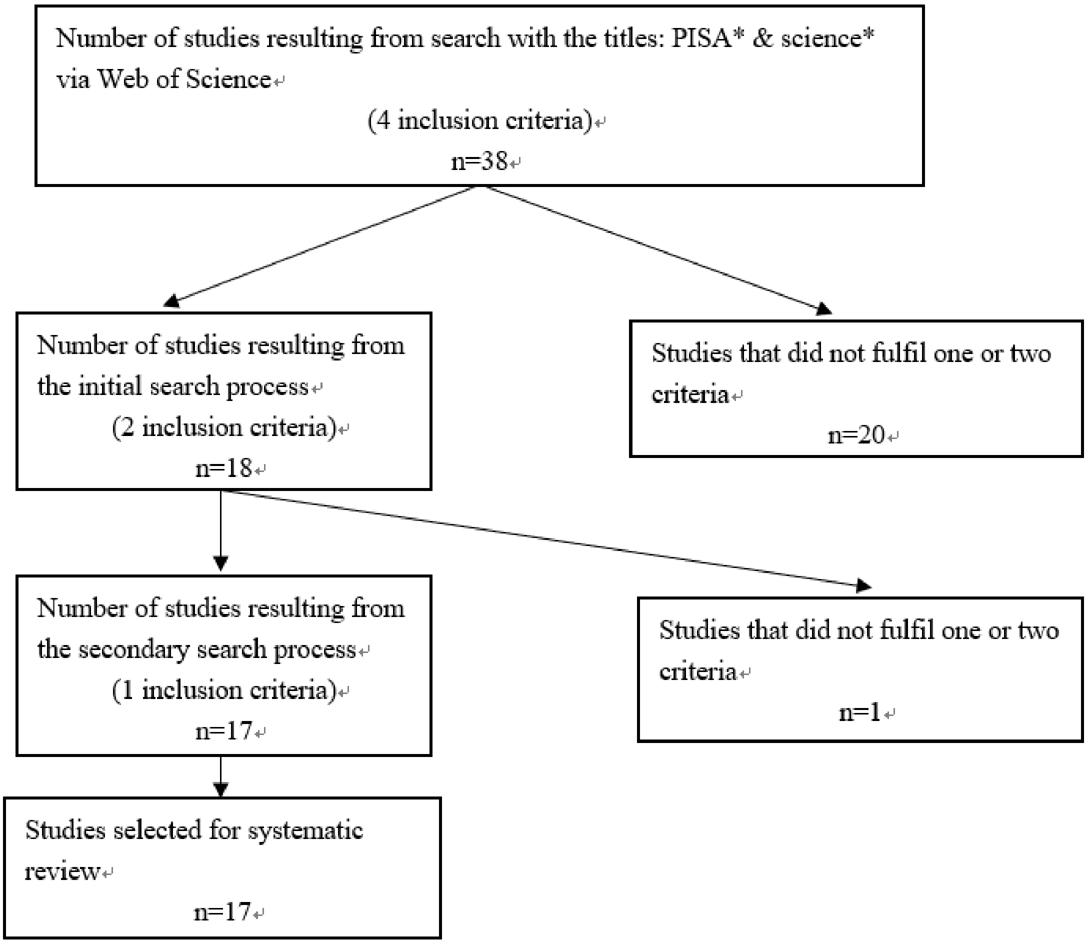

Figure 1 Literature search and sorting flow chart.

Study analysis

Based on the ideas put forward by Petticrew (Petticrew & Roberts, 2006), we designed a table containing the information about the research (author, publication year, sample description, country involved, database and research methods; see Table 1), summarized and compared these studies and researched some relevant variables as described in the following subsections, hoping to clarify the theoretical basis for the influencing factors of PISA science literacy.

Table 1. Overview of the included studies.

Study	Sample	Country	Large-scale data base	Method
Anil (2011)	4,942 students	Turkey	PISA 2006 (Turkey)	Quantitative
Bybee & McCrae (2011)	Students from 20 countries or areas	Australia	PISA 2006	Quantitative
Chi, Liu, Wang, & Won Han (2018)	3.279 students	America, China	PISA 2015(China)	Quantitative
Coll, Dahsah, & Faikhamta (2010)	Students from New Zealand and Thailand	New Zealand, Thailand	PISA 2006 (New Zealand and Thailand)	Qualitative
Gilleece, Cosgrove, & Sofroniou (2010)	4,184 students	Ireland, United Kingdom	PISA 2006 (Ireland)	Quantitative
Ho (2010)	4,645 students	Honk Kong, China	PISA 2006 (Hong Kong)	Quantitative
Jiang & McComas (2015)	191,702 Students	United States of America	PISA 2006	Quantitative
Kjærnsli & Lie (2011)	students from 60 countries	Norway	PISA 2006	Quantitative
Kubiatko & Vlckova (2010)	5,932 students	Czech Republic	PISA 2006 (Czech Republic)	Quantitative
Lau & Lam (2017)	4,000-20,000 students	Hong Kong, China	PISA 2015	Quantitative
Lam & Lau (2014)	4,645students	Hong Kong, China	PISA 2006 (Hong Kong)	Quantitative
Lavonen & Laaksonen (2009)	4,514 students	Finland	PISA 2006 (Finland)	Quantitative
Mikk, Krips, Säälik, & Kalk (2016)	470,000 students	Estonia	PISA 2009	Quantitative
McConney, Oliver, Woods-McConney, Schibeci, & Maor (2014)	41,65 students	Australia, United Kingdom	PISA 2006 (Australia, Canada, New Zealand)	Quantitative
Sun, Bradley, & Akers (2012)	4,645 students	United States of America	PISA 2006 (Hong Kong)	Quantitative
Topçu, Arıkan, & Erbilgin (2015)	9,899 students	Turkey	PISA 2006 2009 (Turkey)	Quantitative
Zhang & Liu (2015)	1,241,031 students	China	PISA 2000 2003 2006 2009 2012	Quantitative

Of the 17 articles, there are 16 quantitative studies, accounting for 94.12% of the total; 1 qualitative study, accounting for 5.88% of the total.

From the country involved in the research of the influencing factors of PISA science literacy, Hong Kong, China and the United States are intensively studied regions/countries, followed by Turkey, Australia, China and the United Kingdom. Considering the continents, Asian researchers (represented by those from Hong Kong, China) and European ones (represented by those from the United Kingdom) are the most active, with 8 articles and 7 articles respectively.

In terms of data sources, 12 of the 17 studies (accounting for 70.59%) researched the data of the 2006 PISA, among which 3 researched the comprehensive data of the 2006 PISA, and the remaining 9 researched the PISA data involving one country/region, or several countries/regions. 2 studies (accounting for 11.77%) researched the PISA data in 2015, one of which used the comprehensive data of PISA 2015 test and the other one used the data of PISA 2015 test in China (B-S-J-G). 1 study (accounting for 5.88%) researched the comprehensive data of the 2009 PISA. 1 study (accounting for 5.88%) researched the PISA data in 2006 and 2009 of the Turkey. In the study carried out by Zhang (Zhang & Liu, 2015), the comprehensive PISA data from 2000 to 2012 was analyzed.

In terms of statistical methods, most of the researches have used correlation analysis, regression analysis, path analysis, HLM and other data analysis methods, while a small number of literatures have used qualitative research methods such as interview and comparison.

RESULT

We summarized the relationship between the influencing factors and PISA science literacy. We refer to our results as “effects” to distinguish between findings based on statistically meaningful tests and the qualitative or descriptive analyses supplementing and explaining quantitative results. In addition, according to the background factor framework of PISA 2015(OECD, 2017), the main influencing factors were divided into three levels: system, school and students. Table 2-4 shows the relationship between the main influencing factors and PISA science performance (Reinhold, Holzberger, & Seidel, 2018).

System level

There are relatively few influencing factors at the system level, and there is no significant relationship between GDP and PISA science performance. As for the role of cultural and social values in science teaching, it is prudent to attribute the best performance in these areas to specific teaching practices, and then to attribute these practices to specific cultural and social values. In addition to teaching practice, there are many factors that play a role in influencing the educational achievements of a region, such as demography, school system, education policy and teacher training (Lau & Lam, 2017).

Table 2. Relationships between system level and PISA science performance.

system level	Effect（PISA science performance）	Study
Ln GDP	ns	Zhang & Liu (2015)
Culture	ns	Lau & Lam (2017)

Note: effect directions with an asterisk indicate statistically significant results, while ns indicates statistically insignificant results. Effect directions without an asterisk does not indicate statistical significance, but is obtained through a descriptive analysis (percentages or frequencies) or a qualitative analysis (e.g. interview).

School level

The influencing factors at school level are mainly divided into three aspects: school background, school policy and teaching practices. Among them, school background is the most frequently studied at school level.

The school background is mainly divided into five aspects: school average socioeconomic status (SES), school type, location of school, school enrolment size and school education resources. School average SES is calculated by integrating the socioeconomic status of all students in the school. All studies found a significant positive correlation between school average SES and PISA science performance. However, Lam (Lam & Lau, 2014) found when the variable of students' academic ability was included, the impact of school SES became insignificant. In addition, in most of the studies, school type, location of school and school enrolment size are significantly and positively correlated with PISA science scores, respectively. To be specific, public schools, well-developed schools and large-scale school enrollment are all conducive to the improvement of PISA performance.

School policy is mainly divided into two aspects: teachers and curriculum setting. The influence of teachers on academic performance is obvious. Just as what Hattie (Hattie, 2009) said, it doesn't matter what school students go to, what teachers they meet is the most important, and the courses and teaching that have a great influence on academic performance are also closely related to teachers. Existing studies mainly focus on teacher professional development, teacher and student behavior, teacher-student relationship and other aspects, and find that there is a significant positive correlation between teachers and PISA science performance. However in the study of teacher-student relationship, at the national level, there are ecological fallacy effects of teacher-student relationship in all PISA countries, but if the geographically and culturally similar regions/countries are compared, there is no negative correlation between teacher-student relationship and PISA science performance (Mikk et al., 2016). In addition, Reasonable curriculum setting can improve students' PISA science scores.

Inquiry teaching is the most frequently discussed teaching practice. Surprisingly, it was found that most inquiry-based teaching practices had a significant negative correlation with PISA science performance. But a study in China shows that Inquiry teaching had a significant positive correlation with low SES students' PISA science achievement. In addition, this study also found that there was a significant relationship between inquiry teaching and control variables such as Self-efficacy related to science, science enjoyment and class size, which indicates that the impact of inquiry teaching on students' PISA science achievement may be regulated by these variables. In other words, these variables may have an indirect impact on students' PISA science achievement through inquiry teaching (Chi et al., 2018).

Table 3. Relationships between school level and PISA science performance.

School level	Effect（PISA science performance）	Study
(a) School background		
School average SES	+*	Lau & Lam (2017)
	+*	Ho (2010)
	+*	Gilleece et al. (2010)
	+*	Zhang & Liu (2015)
	+*	Sun et al. (2012)
	+*	Lam & Lau (2014)
	ns（when the variables of school student academic intake is included）	
School education resources (Class books, laboratory equipment, etc.)	-*(PISA science performance in 2000) +*(PISA science performance in 2003 to 2012)	Zhang & Liu (2015)
School enrolment size	+*	Sun et al. (2012)
	-*	Topçu et al. (2015)
	+*	Lam & Lau (2014)
Location of school	+*	Topçu et al. (2015)
School type	+*	Zhang & Liu (2015)
(b) School policies		
Teacher (Teacher professional development, teacher-student relationship, etc.)	+* (science achievement score at the school and student level) -* (science achievement score at the country level)	Mikk et al. (2016)
	+*	Topçu et al. (2015)
	+*（PISA science performance of students with lower SES）	Chi et al. (2018)

Constructivist-based, learner-centred science curriculum	+	Coll et al. (2010)
(c) Teaching practices		
Inquiry teaching	-* (Interactive Investigation based on inquire teaching) +* (Interactive Application based on inquire teaching)	Lau & Lam (2017)
	Level 0 -Level 4 (Students with level 2 inquiry teaching achieved the highest scientific results)	Jiang & McComas (2015)
	-*	Lavonen & Laaksonen (2009)
	-*	McConney et al. (2014)
	+* (PISA science performance of students with lower SES）	Chi et al. (2018)

Note: effect directions with an asterisk indicate statistically significant results, while ns indicates statistically insignificant results. Effect directions without an asterisk does not indicate statistical significance, but is obtained through a descriptive analysis (percentages or frequencies) or a qualitative analysis (e.g. interview).

Student level

The influencing factors at the student level are mainly divided into three aspects: student background, learning factors and non-cognitive outcomes.

Student background mainly includes gender, student SES, parents' education, cultural resources, Students with immigrant background, grade level and science activities at age 10. Most studies found gender had a significant correlation with PISA science performance, with boys outperforming girls in science. With the exception of Thailand, where a study showed that girls' average science scores were higher than boys', this may be due to Thailand's socio-cultural background. In Thailand, girls are considered more diligent and responsible than boys, and the majority of science teachers in Thailand are women, who tend to give more encouragement to girls in education and teaching (Coll et al., 2010). Student SES is measured by the economic, social and cultural status index (ESCS index) in PISA, which combines factors such as parents' professional status, education, family wealth, family education resources and cultural possession. In most of the studies, there was a significant positive correlation between student SES and PISA science performance. Students from families with high SES performed better than those from families with low SES, which may be due to the fact that students from high SES families can afford all kinds of after-school tutoring. However, a study in Hong Kong found that when the variable of grade level was included, the influence of student SES on their PISA science performance was no longer significant (Lam & Lau, 2014). The other variables of student background had different correlation with PISA science performance, as shown in Table 4.

Students' mastery of information and communication technology (ICT) is the main learning factor for PISA science performance research. The use of program/software on the computer has a significant negative correlation with PISA science performance, which may be because students pay too much attention to program and software problems and fail to allocate enough time for science-related problems. The relationship between independently completing high-level computer operation and PISA science performance varies with the year of PISA test. In addition to the significant positive correlation between the PISA science performance in 2012 and the use of a computer to surf the Internet for fun, there was a significant negative correlation or no significant correlation between the use of a computer to surf the Internet for fun and the PISA science performance. There was a significant positive correlation between the use of computers for online activities (except online entertainment) and PISA science performance.

The non-cognitive outcomes mainly include six aspects: self-efficacy related to science, self-concept related to science, interest in science, science enjoyment, motivation, and Intend to leave school early. In addition to the influence factor of whether students intend to drop out of school or not, the non-cognitive outcomes in most studies are significantly positively correlated with PISA science performance, which also indicates that the non-cognitive outcomes play a crucial role in the formation of scientific literacy. Although there is no significant relationship between the willingness to drop out of school and PISA science performance, there is a significant relationship between its interaction with gender and PISA science performance, specifically, men who intended to leave school early were more likely to have lower science scores than women who intended to leave school early (Gilleece et al., 2010).

Table 4. Relationships between student level and PISA science performance.

Student level	Effect（PISA science performance）	Study
(a) Student background	-*	Lau & Lam (2017)
GIRL (relative to boy)	ns	Lavonen & Laaksonen (2009)
	-*	Ho (2010)
	+ (science literacy scores in Thailand)	Coll et al. (2010)
	ns (science literacy scores in New Zealand)	
	ns	Gilleece et al. (2010)
	-* (science literacy scores in 2003	Zhang & Liu (2015)

	to 2012)	
	ns (science literacy scores in 2000)	
	-*	Sun et al. (2012)
	-*	Lam & Lau (2014)
Student SES	+*	Gilleece et al. (2010)
	+*	Zhang & Liu (2015)
	+*	Lau & Lam (2017)
	+*	Ho (2010)
	+	Coll et al. (2010)
	+*	Sun et al. (2012)
	+*	Lam & Lau (2014)
	ns (when the variables of grade level is controlled)	
Students with immigrant background	+* (PISA science performance in Hong Kong, Macao and Singapore)	Lau & Lam (2017)
	-* (PISA science performance in China, Korea, Canada, Finland)	
	-	Coll et al. (2010)
Grade level	+*	Gilleece et al. (2010)
	+*	Lau & Lam (2017)
	+*	Lam & Lau (2014)
Parents' education	+*	Lavonen & Laaksonen (2009)
	+*	Anil (2011)
	+*	Topçu et al. (2015)
Cultural resources	+*	Gilleece et al. (2010)
	+*	Ho (2010)
	ns	Lam & Lau (2014)
	+*	Topçu et al. (2015)
Science activities at age 10	+*	Ho (2010)
	+*	Lam & Lau (2014)
	ns (when the variables of students' attitudinal factors are controlled)	
(b) learning factors		
Using programs/software on the computer	-*	Zhang & Liu (2015)
	-*	Kubiatko & Vlckova (2010)
Using a computer to surf the Internet for fun	ns (PISA science performance in 2000)	Zhang & Liu (2015)
	-* (PISA science performance in 2003-2009)	
	+* (PISA science performance in	

	2012)	
	-*	Kubiatko & Vlckova (2010)
Ability to independently perform high level computer operations	ns (PISA science performance in 2003) -* (PISA science performance in 2006) +* (PISA science performance in 2009)	Zhang & Liu (2015)
	+*	Kubiatko & Vlckova (2010)
Using a computer for internet tasks	+*	Zhang & Liu (2015)
	+*	Kubiatko & Vlckova (2010)
(c) Non-cognitive outcomes		
Self-efficacy related to science	+*	Lavonen & Laaksonen (2009)
	+*	Sun et al. (2012)
	+*	Lam & Lau (2014)
Self-concept related to science	+*	Lavonen & Laaksonen (2009)
Interest in science	ns	Lavonen & Laaksonen (2009)
	+*	Lam & Lau (2014)
	+*	Bybee & McCrae (2011)
Science enjoyment	ns	Lavonen & Laaksonen (2009)
	+*	Lam & Lau (2014)
Motivation	+*	Sun et al. (2012)
Intend to leave school early: Yes-No	ns	Gilleece et al. (2010)

Note: effect directions with an asterisk indicate statistically significant results, while ns indicates statistically insignificant results. Effect directions without an asterisk does not indicate statistical significance, but is obtained through a descriptive analysis (percentages or frequencies) or a qualitative analysis (e.g. interview).

CONCLUSION

In terms of research contents, most of the studies researched the relationship between the variables of school level and student level and PISA science performance, especially the relationship between student level and PISA science performance. There are few studies on the variables of system level.

As far as the research results are concerned, there are few influencing factors at the system level, and there is no significant relationship between the influencing factors at the system level PISA science scores.

At the school level, there is a significant positive correlation between school average SES and PISA science performance in most studies. Therefore, it is necessary to attach importance to the regulation and control of school average SES, so as to achieve balanced development of different schools in different regions and achieve educational equity to the greatest extent. However, it should be noted that when the variables of school student academic intake is included, the influence of school average SES on PISA science performance becomes insignificant, which indicates that the key to the improvement of performance lies in students themselves. Therefore, it is also very important to strengthen the cultivation of students' cognitive ability and non-cognitive ability. In addition, teacher, as well as the curriculum and teaching closely related to the teachers, have a significant relationship with the PISA science performance. Therefore, the improvement of student PISA performance should start with teacher training. Teachers should first keep up with the pace of innovation, so that students can make changes. The relationship between inquiry teaching and PISA science performance is complex and most studies have found a negative correlation between the two, which may be due to student non-cognitive outcomes, school background, school policy, Teaching and other factors will indirectly affect the student PISA science performance through inquiry teaching. Therefore, inquiry teaching should be reasonably utilized to have a positive impact on the cultivation of PISA science literacy.

At the student level, except for individual studies, gender in most of the studies has a significant negative correlation with PISA science performance. Therefore, it is necessary to attach importance to the disadvantaged status of girls in the process of PISA science literacy cultivation and help female students as much as possible. Meanwhile, it is found that SES also has a significant impact on PISA science performance in most studies, Students from high SES families are more likely to get better grades. The key here may be that students with high SES can afford all kinds of after-school tutoring. Therefore, it is necessary to pay more attention to families’ economic situation and help those children with economic difficulties as much as possible. Different ICT variables have different relations with PISA science performance. The key is to allocate time reasonably, too much time invested in ICT will shorten the learning time of science, which will affect the cultivation of PISA science literacy. Therefore, we should not only cultivate students' computer ability, but also pay attention to the time spent in it. Almost all the non-cognitive outcomes variables are significantly positively correlated with student PISA science performance. Therefore, while teaching students' knowledge, we should cultivate a series of non-cognitive results such as self-efficacy, self-concept, interest in science and so on.

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