

# REGIONAL EDUCATIONAL EQUITY: A SURVEY ON THE ABILITY TO DESIGN SCIENTIFIC EXPERIMENTS OF SIXTH-GRADE STUDENTS

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## Introduction

### *Regional Educational Equity*

In China, there is a vast territory and a large population, the development bases and conditions vary from place to place, so there are problems of large regional differences and the development is not coordinated. Since the implementation of the reform and opening-up policy, China has based on the basic national conditions, drawing on relevant domestic and foreign experience, and achieving a strategic shift from unbalanced development to coordinated development in the gradual exploration. Under the guidance of the regional coordinated development strategy, the developmental gap in various regions has begun to shrink in all directions (Wei, 2018a). However, in the 'Opinions of the Central Committee of the Communist Party of China on Establishing a More Effective Regional Coordination and Development Mechanism' issued in November 2018, 'the regional development gap in China is still relatively large, and the phenomenon of regional differentiation is gradually emerging, disorderly development and vicious competition still exist. The problem of insufficient and imbalanced regional development is still outstanding. The regional development mechanism is still not perfect, and it is difficult to adapt to the strategy needs of implementing a coordinated regional development in the new era' (Xinhua News Agency, 2018). Among them, the educational resources have a clear gap in the investment of education between urban and rural areas, the advantages and disadvantages of running schools between urban and rural areas are significant, and the reality of the imbalance between the distribution of teachers in urban and rural primary and secondary schools is evident (Tan, 2017). The coordinated development of regional education is an important part of regional coordinated development.

The report of the 18th National Congress of the Communist Party of China (2012) clearly pointed out that 'we should vigorously promote



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**Abstract.** *Due to the vast territory, there are problems of unbalanced development of education and students' ability level in China. In order to explore the relation between regional education equity and the development of students' scientific ability, and to better promote the development of education and students' growth, it is urgent to carry out the research. In the context of regional coordinated development, stratified random sampling and cluster sampling were used to study the ability to design scientific experiments of 742 sixth-grade students in Beijing. The results showed that, first of all, the ability to design scientific experiments of 742 sixth-grade students in Beijing was low and the developmental level was not coordinated. Secondly, there was a significant correlation between gender and students' ability to design scientific experiments. In addition, there was a significant negative correlation between districts and the ability to guess and predict. Finally, significant positive correlations were found among the internal structures of ability to design scientific experiments. Therefore, in order to promote the coordinated development of students' ability to design scientific experiments, this paper puts forward effective suggestions in four aspects: improving science teachers' professionalism, offering experimental resources, updating teaching philosophy and strengthening curriculum construction.*

**Keywords:** *experimental design, primary school students, regional educational equity, science education, scientific experiments.*

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education equity, rationally allocate educational resources, and focus on rural, remote, poverty, and ethnic areas. *The report of the 19th National Congress of the Communist Party of China* puts more emphasis on 'prioritizing the development of education... promoting education equity... promoting the integrated development of urban and rural compulsory education' (Xinhua Net, 2018). In the context of coordinated regional development, promoting the coordinated development of education has become a prominent task of China's current education development and a special concern of management (Tian, Wang, & Zheng, 2011). 'Coordinated development of education' mainly refers to the state in which the factors that constitute the development of education conform to the law, the structure formed by it is organically unified and in a state of benign interaction with the external environment (economic and social development needs), the development of education reflects the unity of purpose and regularity (Sang, 2010). Within the region where education is coordinated and developed, there are no or a few educational pathological phenomena or educational dysfunctions such as 'educational conflicts' and 'educational differences' (Siakas, Rahanu, Georgiadou, & Paltalidis, 2013). In order to prevent and detect the existence of educational disharmony or imbalance of education within the education system, it is necessary to make a diagnosis of the education in the region. The main body of education is students, the outcome of the coordinated development of a regional education scale, structure, quality and efficiency ultimately needs to be reflected in the quality of talent training.

*The report of the 19th National Congress* pointed out that it is necessary to 'accelerate the construction of an innovative country... to cultivate a large number of strategic scientific and technological talents, leading scientific and technological talents, young scientific and technological talents and high-level innovation teams with international standards' (Xinhua Net, 2018). It can be seen that the cultivation of scientific and technological talents has a major construction effect on the prosperity of the country, and the training of scientific ability and technological talents needs to be started from elementary education (Guo, 1995). Ability to design scientific experiments is a basic and key scientific ability, carrying out experimental design activities and cultivating experimental design thinking in the basic education stage, and it will lay a solid foundation for the growth of scientific and technological talents and provide potential power for national technological innovation.

### Scientific Experiments

Scientific experiments have been recognized as an effective way to conduct hands-on inquiry-based learning (Roth & Roychoudhury, 1993; Rutherford, 1964; Schon, 1983). Scientific inquiry as a scientific method in the field of natural science was first proposed by Dewey and applied to science education (Rowland, 2018). In 1961, Schwab officially put forward the idea of scientific inquiry in the report of "Science Teaching as Inquiry", and supported that the role of the laboratory to demonstrate the inquiry process should be exerted (Craig, 2008), help students understand the establishment and development of science. Since the 1970s and 1980s, many countries have begun a series of attempts at the reform of inquiry science education. In 1994, the World Science Alliance Scientific Capacity Building Committee (ICSU-CCBS) was established to promote the reform of science education in developing countries (Wei, 2018b). The committee held an international conference in Beijing in 2001 and published the *Beijing Declaration*, which opened the prelude to China's science education reform. After nearly a decade of development, science education reform has made great progress in the fields of curriculum, teaching and evaluation (Wei, 2018b).

However, there have also been some problems in mechanization, superficialization and formalization, such as the tendency of teachers to directly teach or train scientific ideas or operational skills (Berry & Cassandra 2017), and equate inquiry teaching with the hands-on activities of skill training (Craig, 2008). At present, there are some formal and mechanistic problems in the teaching of scientific experiments, such as the teaching style of recipes and the teaching forms of taking prescriptions (Markow & Lonning, 1998). When conducting experiments in a mechanized and formal way, students are unable to purposefully collect and record data, and they are less likely to establish meaningful internal connections between concepts (Roth, 1994). These forms of teaching are not conducive to the development of students' higher-order thinking ability and the cultivation of inquiry ability, and are not conducive to students' understanding of the nature of science and the spirit of science (Roth & Roychoudhury, 1993).



### *Experimental Design Ability*

Experimental design ability is not only the core thinking ability in scientific learning, but also the embodiment of higher-order thinking ability. Bloom divided learning goals into three domains: cognition, emotion and movement, among which the cognitive domain attracts the most attention. The cognitive domain can be further divided into six domains: memory, understanding, application, analysis, evaluation and creation (Anderson et al., 2001; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Ogilvie (2009) classified scientific thinking ability into high-level scientific thinking ability and low-level scientific thinking ability according to Bloom's taxonomy. Analysis ability, evaluation ability and creation ability are important components of experimental design ability. Researchers at home and abroad have put forward their understanding of scientific experimental ability from different perspectives (Wan, 2008). Guo (2005) supported that the ability of experimental design includes three indicators: experimental principle, experimental plan and experimental reflection. Specifically, it can describe experimental principle, write chemical equations, list drugs and equipment, write experimental steps, consider the diversity of experimental schemes and choose feasible ones for implementation, etc. Students are assessed on their ability to design scientific experiments in chemistry at different levels of planning, applying scientific knowledge and acquiring data (GCSE, 1996). Wilhelm and Beizhuisen (2014) found that the hypothesis, experiment, evidence evaluation and reasoning skills involved in scientific inquiry are highly correlated. Karelina and Etkina (2007) believed that the process of experimental design involves analyzing experimental data, predicting experimental results and revising hypotheses.

Scientific experiment design plays a positive role in cultivating creativity, improving problem solving ability, promoting concept understanding, enhancing sense of responsibility, exercising meta-cognitive thinking and developing language ability. Yang, Wang, Wang, Tang and Wu (2018) believed that design-based experimental teaching can cultivate students' problem-solving ability and innovation ability. Problems in the real world that are poorly defined, poorly informed, or lacking given answers require the application of higher-order thinking skills to better solve them (Fortus, Dershimer, Krajcik, Marx, & Mamloknaaman, 2010). Etkina et al. (2010) believed that experimental design containing higher-order thinking ability provides students with opportunities to participate in real scientific tasks. In solving the task of simulating real-world challenges, innovative solutions are proposed, and students' problem-solving ability and creativity are effectively developed.

Irwanto, Rohaeti and Kolonial (2018) argued, experiments are the best way to solve problems, since scientific information from different sources needs to be considered in experiments. As one of the experimental ability, experimental design ability is related to scientific process ability, and both of them are helpful for students to understand concepts and apply concepts to solve various problems. Bullock, Sodian and Koerber (2009) also found that the early understanding of experimental design can be applied to later learning strategies, and the use of early strategies is also conducive to the later concept understanding. Etkina et al. (2010) also found that students' scientific thinking habits can be developed by involving them in the design of real or virtual experiments. In addition, in the process of participating in the experimental design, learners enhance their sense of responsibility for learning by planning, evaluating, modifying activities and reflecting on the process (Hmelo, Holton, & Kolodner, 2000). In the process of experimental design, students' meta-cognitive thinking such as planning, monitoring and evaluation is exercised (Campione, Shapiro, & Brown, 1995). Finally, in the process of communicating with others, students must use scientific language such as thinking, evaluation, action and interaction, which also helps students develop their language ability (Davidowitz & Rollnick, 2003). Therefore, in order to produce the best learning effect and better improve learning performance, Cigrik and Ozkan (2015) believed that educators should systematically measure and evaluate students' scientific experimental design ability.

On the basis of clarifying the structure of scientific experimental design ability, many scholars have made some attempts to measure and evaluate the students' ability to design scientific experiments in some areas. For example, Wan (2008) analyzed and evaluated the ability to design experiments of eighth-grade students in Guangxi province. The results showed that the overall experimental thinking level of eighth-grade students was not high. The specific difficulties include lack of effective connection between life or learning experience and problem to be solved; lack of dialectical 'prove' tendency, ignoring the habit of thinking from opposite angles at the same time; lack of anticipation of experimental results; insufficient experimental design experience and lack of experimental problem solving prototype; lack of basic procedural knowledge and strategic knowledge of design experiment; lack of the ability to evaluate experiments etc. Hu (2007) studied the biological experiment design ability of high school students and pointed out that there are problems in teacher quality, individual



student differences and experimental implementation. Li (2007) also conducted a relevant investigation and research on the biological experiment design ability of high school students, and suggested that there were some problems: Students' experimental design awareness is not strong, science teachers' experimental teaching is lagging, teaching methods are rigid, teaching materials are less experimentally designed, and lack of experimental design related knowledge. In addition, many researchers have made a series of attempts to improve the experimental design of students and proposed many intervention measures (Zhang, 2018; Xue, 2007).

To sum up, it is particularly necessary to diagnose and measure students' ability to design scientific experiments in the stage of basic education, and to determine the current situation of students' experimental design level in the region, so as to improve students' exploration ability and coordinate the development of regional education.

### *Research Focus*

Therefore, in view of the significance and current problems of scientific experiment design, the purpose of this research identified as the following three points: Firstly, it is to have a comprehensive understanding of the current situation of students' experimental design ability in Beijing. Secondly, it is to enable researchers to have a clearer grasp of students' scientific process ability. Finally, it is to provide science teachers with guidance and suggestions for cultivating primary school students' experimental design ability, so that science teachers can carry out more targeted and accurate teaching.

According to the research purpose, the research questions could be summarized as follows: (1) whether the development level of ability to design scientific experiments of sixth-grade students in Beijing is coordinated? (2) what is the correlation between the ability to design scientific experiments of students from different regions and genders in Beijing? (3) what is the relation between the internal structure of scientific experimental design ability?

## **Research Methodology**

### *General Background*

This research was conducted by strategy of a survey and method of questioning which all meet the needs of the corresponding research purposes. The survey approach is the research strategy that asks multiple individuals about one or more topics and then describes their reactions (Jackson, 2016). The method of questioning has the advantages of anonymity, low cost and high efficiency, and collecting a large amount of required data in a short time (Denscombe, 2007). This survey was completed within one month of the end of the fall semester of 2018, provided that the students have completed all of the experimental courses. As a type of correlational research, taking the gender and the region of the student as the independent variables, and taking the students' ability to design experiments as the dependent variable, the correlation between the gender, region and experimental design ability was studied. The results could provide a reference for science teachers and researchers to understand the status of students' ability to design scientific experiments, and further directions for teaching improvement and teaching guidance.

### *Research Sample*

This research firstly conducted stratified random sampling of various districts in Beijing according to the five directions of the east, west, south, north and center. Pinggu District and Shunyi District was selected from eastern direction, as well as, Shijingshan District and Changping District was selected from western direction. The southern direction was selected for two districts including Daxing District and Tongzhou District. The selected districts in the north include Yanqing District, and the selected districts in the central include four districts: Dongcheng District, Xicheng District, Chaoyang District and Haidian District. Secondly, 1~2 primary schools are randomly selected from each district. Finally, 1~2 classes were randomly selected from the sixth grade of each elementary school by using cluster sampling method, and 749 students from age 10 to 12 were selected. Finally, 742 valid samples were collected after deleting invalid data, and the survey completion rate was 99.07%. The samples distribution is shown in Table 1.



**Table 1. Distribution of samples.**

Directions (Numbers)	Districts	Gender		N	Percentage(%)	
		Boys	Girls		Boys	Girls
Central (310)	Haidian	78	68	146	53	47
	Dongcheng	32	33	65	49	51
	Xicheng	17	16	33	52	47
	Chaoyang	28	38	66	42	58
Eastern (80)	Pinggu	21	24	45	47	53
	Shunyi	16	19	35	46	54
Western (136)	Changping	37	31	68	54	46
	Shijingshan	32	36	68	47	53
Southern (142)	Daxing	29	30	59	49	51
	Tongzhou	41	42	83	49	51
Northern (74)	Huairou	11	12	23	48	52
	Yanqing	27	24	51	53	47

#### Instrument and Procedures

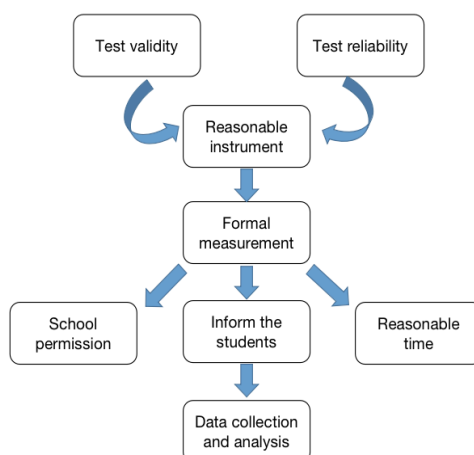
Developing effective and credible research instrument is an important part of research. Before the development of research instrument, a detailed review of the evaluation of ability to design scientific experiments was made. (Guo, 2005; Ministry of Education of the People's Republic of China, 2011). Combining the evaluation framework of experimental design ability of domestic and foreign researchers, the ability to design scientific experiments is finally divided into five assessment indicators: guessing, planning, variables, reflection and prediction. Each indicator is further divided into two secondary indicators, which are scored according to 3 point, 2 point, 1 point, and 0 point. The minimum possible score for each question is 0, and the highest score is 30. The low level is between 0 to 10, the medium level is between 11 to 20, the medium level is between 21 to 30; The total score between 0 and 20 is divided into low level, the total score between 21 and 40 is divided into low level, and 41~60 is high level. By appropriately refining the level of scientific experimental design of students, the degree of discrimination of the evaluation system can be better improved.

TIMSS is a standardized standard test that scores the scores of non-choice questions using a two-digit scoring code, the correct answer or a reasonable answer can be scored. This research evaluates students' ability to design scientific experiments with reference to the TIMSS hierarchical coding scale. In addition, the test preparation and evaluation criteria also draw on the evaluation concepts and characteristics of the horizontal classification of students in the PISA2018 scientific literacy assessment. At the same time, combined with the content of *China's Primary School Science Curriculum Standards* and scientific textbooks (Ministry of Education of the People's Republic of China, 2017). Comply with the principles of normativeness, suitability and situationality, compile experimental design ability questionnaire. The questionnaire contains questions 1 and 2, which respectively reflect the situation of material science problems and life science problems, and embodies five evaluation indicators in the evaluation criteria.

First, the experimental design ability questionnaire was used for pre-experiment. Three experts verified the questionnaire of experimental design ability, and then the questionnaire was randomly distributed to 113 students in the sixth grade of Beijing. The results proved that the surface validity of the questionnaire meets the requirements. Secondly, the construct validity of the questionnaire was analyzed. The KMO sampling adequacy is .726, which is higher than the requirement of .600 for the validity of the questionnaire, and the construct validity is acceptable (Hutcheson & Sofroniou, 1999). Finally, the reliability of the questionnaire was analyzed. The questionnaire was scored by two uniformly trained researchers, the results showed that the Cronbach's alpha coefficient was .906, which has good reliability (Nunnally & Bernstein, 1994), it indicates that the experimental design ability scale can reasonably measure student performance.



First, the implementation of this research was approved by the head of the school, and students were informed of the completion requirements and research purposes during the measurement process. Secondly, they were also informed that the measurement results were not evaluative and were used only for research purposes. Finally, the estimated completion time of the questionnaire was 30 minutes, and all students complete the task independently within the required time. The measurement procedure is shown in Figure 1.



**Figure 1.** The procedure of measurement.

#### *Data Analysis*

The description statistics and correlation analysis were completed in the part of data analysis. The descriptive statistics was used to determine students' demographics and scores of ability to design experiments in this research by means of average score, standard deviation, extreme value and percentage of data. In addition, the independent sample *t*-test and the homogeneity test of variance were used to determine the significance of the average scores of students in different genders and regions. According to Creswell (2008), correlation analysis aims to understand the correlation of two or more research variables. Pearson correlation was also used to measure the correlation between scores of two different questions, the significant correlation between gender, region and the students' ability to design experiments, as well as the correlation between the secondary indicators of ability to design experiments. The significance level was set at .05. The acquired data was used by SPSS 23.0 (SPSS Inc., Chicago, IL, USA).

#### **Research Results**

##### *The Overall Level of Students' Ability to Design Scientific Experiments*

The level of students' ability to design scientific experiments was obtained from the effective questionnaire of ability to design scientific experiments. The data analysis results show that the average level of scientific experimental design of the students is at the low level. As shown in Table 2, first, students with a high level of ability to design scientific experiments account for only 5%, and students' overall ability to design scientific experiments is low ( $M=23.50$ ,  $SD=9.866$ ). Second, the average score of the first question is 2.20 higher than the average score of the second question, and the degree of dispersion of the second question is more. Third, students in the middle and high levels of question 1 are more than the question 2, but the students who are at a low level in question 1 are less than those who are at a low level in question 2. Fourthly, the Pearson correlation was used to analyze the first and the second questions. The results show that  $p < .01$ , the scores of the first question and the second question are significantly positively correlated.



**Table 2. The overall level of students' ability to design scientific experiments.**

Question	N	Max	Min	M	SD	Level (Percentage)			Correlation Coefficient	p
						Low (percentage)	medium (percentage)	High (percentage)		
1	742	27	0	13.75	5.464	20 (28)	46 (63)	68 (9)	.533**	.01
2	742	26	0	11.55	5.805	28 (38)	43 (58)	27 (4)		
Total	742	51	2	23.50	9.866	23 (32)	46 (63)	36 (5)		

Note: \*\*Correlation is significant at the .01 level (2-tailed).

The students' ability to design scientific experiments consists of five parts: guessing, planning, variables, reflection and prediction, as shown in Table 3. The results show that, firstly, students in all four sections receive full marks (the maximum value of a single part was 12), and students in all five parts don't score (minimum of 0). However, the maximum value of the reflection part is 10, and no student gets a perfect score. Second, the student has the highest average score in the guessing part ( $M = 7.46$ ), while the average score in the variable and predicted part is the lowest, indicating that the average level of guessing ability of students is the highest, but the average level of variables and predictions is lower. Third, students have the least degree of dispersion in the reflection part, but the degree of dispersion in the variables part is the largest. Fourth, from the percentage of the total score of the ability to design experiments, the guessing part accounts for the largest proportion, while the prediction part accounts for the smallest proportion.

**Table 3. Descriptive statistics of ability to design scientific experiments.**

Ability to Dsign Experiments	Max	Min	M	SD	Percentage (%)
Guessing	12	0	7.46	2.304	29
Planning	12	0	5.28	2.663	21
Variables	12	0	4.71	3.065	19
Reflection	10	0	4.74	2.182	19
Prediction	12	0	3.10	2.656	12

#### *Students' Ability to Design Scientific Experiments of Different Genders*

On the one hand, as shown in Table 4, the results of the Levene's test show that the  $p$  value of gender and each variable is greater than .05, which meets the requirement of homogeneity of variance. Further independent sample t-test for boys and girls in the score of first question, the score of second question, the five first-level ability and the total score. The results show that there is no significant difference between the two levels of ability and gender in conjecture and reflection. Boys and girls have significant differences in the first-question score, the second-question score, the two-question total score, and the three first-level abilities of planning, variables, and prediction ( $p < .05$ ). And in all dimensions, the average score of girls was higher than that of boys. In addition to the ability of guessing and reflection, the scores of girls are more discrete than boys.



**Table 4. Independent sample t-test for ability to design experiments and gender.**

Ability to Dsgin Experiments	Gender	N	M±SD	Levene's Test for Equality of Variances		p
				F	Sig. (2-tailed)	
Question 1	Boys	368	13.16±5.367	.010	.922	.003
	Girls	374	14.33±5.503			
Question 2	Boys	368	10.88±5.730	.087	.768	.002
	Girls	373	12.20±5.811			
Guessing	Boys	368	7.31±2.359	2.336	.127	.082
	Girls	374	7.60±2.242			
Planning	Boys	368	4.99±2.605	.869	.352	.004
	Girls	374	5.56±2.692			
Variables	Boys	368	4.37±2.992	.864	.353	.003
	Girls	374	5.04±3.104			
Reflection	Boys	368	4.57±2.240	2.579	.109	.032
	Girls	374	4.91±2.113			
Prediction	Boys	368	2.80±2.512	2.970	.085	.002
	Girls	374	3.40±2.761			
Total	Boys	368	24.04±9.656	.063	.802	.001
	Girls	374	26.51±9.931			

On the other hand, from the Pearson correlation analysis results in Table 5, there is a significant positive correlation between the students' gender and question one, question two, guessing, planning, variables, reflection, prediction, and total scores. The research found that girls scored higher than boys in terms of overall ability to design scientific experiments and the level of ability to guess, plan, variable, reflect, and predict.

**Table 5. Pearson's correlation coefficient for ability to design experiments and gender.**

		Question 1	Question 2	Guessing	Planning	Variables	Reflection	Prediction	Total
Gender	Correlation Coefficient	.107**	.114**	.064*	.107**	.110**	.079*	.113**	.125**
	Sig. (2-tailed)	.003	.002	.082	.004	.003	.032	.002	.001
	N	742	741	742	742	742	742	742	742

Note: \*\*Correlation is significant at the .01 level (2-tailed).

\*Correlation is significant at the .05 level (2-tailed).

#### *Gap in Students' Ability to Design Scientific Experiments Based on Distracts*

First, a one-way ANOVA of variance in the students' ability to design scientific experiments from different districts shows that the differences in guessing, planning, variables, reflection, prediction are statistically significant ( $p < .05$ ). There is a significant difference between the districts and students' experimental design. Moreover, there is a significant difference in the total ability of regional and student experimental design, that is, different districts have an impact on students' experimental design ability, as shown in Table 6. Second, the LSD results show that students in the southern district score the highest in terms of experimental guessing ability, and students in the northern district score lower than the other four regions. In the experimental planning ability, students in the central district score the highest, while those in the western district score the lowest. In the experimental planning





ability, students in the central district score the highest, while those in the western district score the lowest. In the variable ability, the students in the central district score the highest, the students in the eastern district score the lowest; the performance in the predictive ability, the reflective ability and the total score are consistent, and the students in the southern district score the highest, while the students in the eastern district score the lowest.

**Table 6. Gap in students' ability to design experiments based on districts.**

Ability to Design Experiments	Central District	Eastern District	Western District	Southern District	Northern District	F
Question 1	14.210± 5.3163	11.813± 5.3227	12.934± 5.2426	15.232± 5.2331	12.608± 6.0970	7.497**
Question 2	12.406± 5.5845	8.313± 5.9376	10.882± 4.9800	12.951± 5.9314	9.797± 6.0906	12.830**
Guessing	7.777± 2.0540	7.125± 2.4307	7.059± 2.5115	8.155± 1.7677	5.878± 2.7596	13.074**
Planning	5.765± 2.6899	3.538± 2.2101	4.919± 2.3603	5.606± 2.4609	5.189± 3.0461	16.080**
Variables	5.026± 2.9493	3.663± 3.1700	4.934± 3.1274	4.641± 2.9854	4.230± 3.2289	13.112**
Reflection	5.048± 2.1181	3.800± 2.3621	4.699± 2.0917	5.049± 1.9798	3.986± 2.3495	3.870**
Prediction	3.000± 2.3469	2.000± 1.8759	2.257± 2.3570	4.732± 3.0456	3.122± 2.8999	8.520**
Total	26.616± 9.5204	20.125± 9.5882	23.816± 8.6369	28.183± 9.7839	22.405± 10.7994	22.771**

Note: \*\*Correlation is significant at the .01 level (2-tailed).

Third, a correlation analysis of the districts and the students' ability to design scientific experiments is given in Table 7. Among the five abilities, there is a significant negative correlation between the districts, guessing ability and the reflective ability, and there is a significant positive correlation between the district and the prediction. Among them, there is a low correlation between districts and reflection ( $r = .078, p < .05$ ), and district is moderately related to guessing ability and reflective ability.

**Table 7. Pearson's correlation coefficient for ability to design experiments and districts.**

		Guessing	Planning	Variables	Reflection	Prediction
District	Pearson Correlation	-.125**	-.045	-.058	-.078*	.136**
	Sig.(2-tailed)	.001	.221	.107	.033	.000
	N	742	742	742	742	742

Note: \*\*Correlation is significant at the .01 level (2-tailed).

\*Correlation is significant at the .05 level (2-tailed).

#### *The Relation between the Internal Structure of Ability to Design Scientific Experiments*

Pearson correlation analysis was used to test the relation between the internal structure of experimental design ability. The results are shown in Table 8. At the level of .01, there is a significant positive correlation between the five dimensions, indicating a close correlation between guessing, planning, variables, reflection, and prediction. Students with high guessing ability scores have higher plans, variables, reflections, and predictive abilities. Students' mastery of one of these skills will affect the development of other skills.



**Table 8. Pearson's correlation coefficient for internal structure of ability to design experiments.**

Ability to Design Experiments	Guessing	Planning	Variables	Reflection	Prediction
Guessing	1.000				
Planning	.233**	1.000			
Variables	.133**	.721**	1.000		
Reflection	.238**	.755**	.785**	1.000	
Prediction	.238**	.557**	.506**	.554**	1.000

Note: \*\*Correlation is significant at the .01 level (2-tailed).

## Discussion

Based on gender, region and internal ability structure, this study investigated the coordinated development of ability to design scientific experiments of sixth-grade students in Beijing primary schools. Firstly, the overall scientific experiment level of students was described and statistically analyzed, and Pearson correlation was used to analyze the two questions. Secondly, the differences of students' ability to design scientific experiments between different genders were analyzed, and then the differences of students' ability to design scientific experiments in different districts were analyzed. Finally, the relation between the internal structure of ability to design scientific experiments was analyzed.

The results showed that the overall scientific experiment level of the sixth-grade students in Beijing primary school was below the average level, and the students' ability to design scientific experiments was low. Firstly, in terms of the distribution of ability, the experimental design level of different individuals in the student population varied greatly. For example, the highest score of the total score (the full score was 60 points) is 51, while the lowest score was only 2.

Secondly, in the performance of different problem situations, the average score of students in the material science problem situation of question one was higher than that of the life science problem situation of question two, but the dispersion degree of the score of material science situation was greater, and the ability performance tended to be polarized. According to the analysis of the questions, the different performance of students in different question situations may be caused by the different openness of the questions. Compared with life science question, material science questions give students more specific feedback information in terms of planning, variables and reflection. When students understand the information in the questions, they will have a positive guiding effect on their experimental design process. In fact, support information in material science issues potentially provides students with mental scaffolding. Hmelo, Holton and Kolodner (2000) believed that providing various scaffolds in teaching can help students understand the complex system of experimental design. Etkina et al. (2010) said that the introduction of scaffolding in experimental design activities can help students develop scientific thinking ability. However, compared with material science questions, life science questions have less supporting information, and students need to design experiments based on the logic and steps already in mind, and these differences are reflected in the differences in average scores. In addition, there was a significant correlation between students' scores in material science and life science, indicating that students who score high in material science also scored high in life science. Although the first question was about the material science situation and the second question was about the life science situation, the two questions had different problem situations, but the correlation between the scores of the two questions indicates that the students' experimental design ability under different problem situations has certain mobility. That is to say, students with high ability to design experiments show higher ability level when facing different problems; Students with low ability to design experiments also have low performance in different situations.

Thirdly, from the perspective of the structure of ability to design experiments, students scored the highest in the guessing ability, with the smallest dispersion degree, and the guessing part accounted for the largest proportion of the total score (29%). In contrast, students performed worst in the variables and predictions section, with an average score of only about a third of the guessing and a high degree of dispersion. According to the standard of science curriculum for primary schools of compulsory education, the goal of scientific inquiry in grade 5 to 6 is



to make a relatively complete plan of inquiry based on the knowledge learned, have the initial ability to design experiments and the consciousness of controlling variables, and be able to design the experimental scheme of a single variable (Ministry of Education of the People's Republic of China, 2017). However, most students in the study have not met the requirements of the course standard. Etkina et al. (2010) believed that when students encounter problems in the experimental design, the experimental instructor shouldn't directly tell them how to design the experiment, he should provide indirect help, for example, you can ask guidance questions and provide further tips. Therefore, it is necessary for science teachers to provide students with scaffolding as support information in experimental design.

Students of different genders had significant differences in the overall ability and sub-ability to design scientific experiments. In terms of ability to design experiments, the average score of girls was 2.47 higher than the average score of boys. Girls also scored higher than boys in the substructure of ability to design experiments -- guessing, planning, variables, reflection and prediction. Similar results have been shown in previous studies. Aydinli et al. (2011) and Dönmez and Azizoğlu (2010) also found similar studies. In another study, Guevara (2015) applied an innovative method to the teaching of common biology and tried to prove whether gender influences students' performance. It turned out that girls had higher process ability scores than boys. In other studies, Seetee, Coll, Boonprakob and Dahsah (2016) and Zorlu, Zorlu and Sezek (2013) have reported similar results. According to the report of Dhindsa and Chung (2003), this phenomenon may occur because girls have stronger sense of responsibility than boys in learning chemistry through experimental activities. In addition, Chan and Norlizah (2017), Majere, Role and Makewa (2012) also believed that women have more positive attitudes, perceptions and motivations than men. In addition, the students who scored highest in the second and overall scores were also girls. However, this finding does not match the findings of Beaumont-Walters and Soyibo (2001) and Obialor, Osuafor and Nnadi (2017), who pointed out that although boys tend to score higher than girls, there was no significant gender difference in students' scores. Some scholars pointed out that different results may be related to the rapid development of women's liberation movement (Jatiningsih, 2017). The findings suggest that stereotypes and social conventions of boys superiority are breaking down.

Students from different districts had different performance in ability to design scientific experiments. The students in the south and the middle of Beijing had better ability to design scientific experiments, while the students in the east and the north of Beijing had worse ability to design scientific experiments. Students from the central district, Haidian District and Xicheng District performed better, and students from Daxing district in the southern district performed best. According to the results of one-way ANOVA, there are significant differences in different degrees among different districts. In order to explain the reasons, Antonelli, Crepax and Fassio (2013) found that advanced scientific knowledge could be transformed into technical knowledge with a high level of substitutability, appropriateness, accumulation and complementarity, which may affect economic growth. Rindermann and Thompson (2011) found that wealth and economic freedom also had positive effects on cognitive ability in the longitudinal direction. The degree and level of economic development of different districts in Beijing are different, and there are also differences in regional functional orientation. They are divided into four functional areas: Capital Functional Core Area, Urban Function Development Area, Urban Development New Area and Ecological Conservation Development Zone (Zhao, 2016). It can be found that students' ability to design scientific experiments has a certain relation with economic development and regional functional positioning. In addition, education as a superstructure is bound to be influenced by the economic base (Wang, Yuan, Tian, & Zhang, 2013).

However, the level of ability to design scientific experiments and economic ranking of students are not completely consistent, indicating that education has its own independence and is influenced by science teachers, teaching materials and teaching methods. For example, although they are based on uniform curriculum standards, the textbooks in each district are not completely consistent. According to the research of the employment intention of students majoring in education, personal future development factors, living conditions factors, teaching condition factors, and marital problems have significant influence on the science teacher's willingness to teach (Liu & Fang, 2015). In the central district, these conditions are often superior, so the central district is more attractive to quality science teachers. Finally, the direct factor affecting experimental design ability is experimental resources. Due to the different levels of economic development in each region, the ability of the sample schools to have laboratories and supporting equipment is different, as pointed out by Myers and Dyer (2006), students who were learning through inquiry lab teaching had stronger scientific process ability and more complete content knowledge than those using regular experimental learning methods. So lab-learning plays an important role in the development of students' ability to design scientific experiments. In addition,



external factors such as regional cultural atmosphere and family composition may also mediate experimental design ability, which need further study.

There is a significant positive correlation between the dimensions of students' ability to design scientific experiments in Beijing. When one of the students' ability is high, the other abilities are often higher. Similarly, when one of the students' ability is low, the development of several other abilities often have obstacles. This finding is similar to the results of Özgelen (2012). Özgelen (2012) investigated the scientific process ability of 306 sixth-grade and seventh-grade students within the framework of cognitive domains, and found that the exercise of scientific process ability had indeed improved students' thinking, reasoning, inquiry, evaluation, problem solving and creativity. A study by Rabacal (2016) also confirmed a positive correlation between student base and comprehensive science process skills, and suggested that students improve their performance through experimental exercises. Farsakoğlu, Şahin and Karsli (2012) also suggested that ability performance could be improved through meaningful hands-on experiments. Research has proved that as a part of scientific process ability, the internal structure constitutes a unified organic whole. The development of ability to design scientific experiments needs to be carried out in a coordinated and comprehensive manner, with strong ability to drive inferior ability, and consistently play a synergistic role to improve ability to design scientific experiments.

## Conclusions

As the representative of the highest level of primary school ability in Beijing, the overall level of ability to design scientific experiments of sixth-grade students is at the low levels, and there are significant imbalances in different districts, gender and internal structure. The coordinated development of education is an important part of regional coordinated development. The balanced development of students' ability level is the key to the coordinated development of education. The ability to design scientific experiments is closely related to students' scientific ability, which has a stronger potential role in promoting innovation ability. Therefore, it is necessary to take positive measures to promote the comprehensive and balanced development of students' scientific experiment ability in the whole region. Based on the research results, we can enhance and improve it from the following aspects.

Firstly, science teachers are the direct promoters to promote the development of students' scientific ability. Therefore, science teachers should first identify and understand the importance of developing students' ability to design scientific experiments ideologically. In addition, because science teachers' experimental ability directly affects students' scientific inquiry ability, science teachers must strive to improve their own ability to design scientific experiments and quality, and implement the requirements of scientific experiment design from the action. Secondly, the development and utilization of curriculum resources should be strengthened, the complete framework of ability to design scientific experiments and matching resources to develop ability to design scientific experiments should be constructed, so as to provide sufficient laboratory activities for students. Laboratory is not only the most important resource for students to learn science, but also the main learning place. It plays an irreplaceable role in the formation of students' scientific literacy. Thirdly, science teacher should renew the concept of experimental teaching, implement the experimental teaching mode based on design with the development of inquiry ability as the core, improve the thinking level and skills of experimental design, and cultivate students' scientific thinking. Fourthly, schools should strengthen the curriculum construction of scientific experiment design, explore the exploratory function of experiments in existing textbooks, and supplement extracurricular experiments with school-based courses and research-based learning, so as to gradually cultivate students' experimental interest and ability to design experiments in scientific practice.

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