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RESEARCH ON THE COGNITIVE LEVEL OF STUDENTS' PERCEPTIONS OF PHYSICS MODELS AND MODELING MECHANISM IN CHINESE HIGH SCHOOLS

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Abstract. *Scientific model has been advocated as a central role of teaching in science education reform all over the world, with the critical method to achieve one of the goals of science education to promote scientific models and modeling. To find the students' perceptions of cognitive level of physics models and their modeling mechanism, firstly, research progress in scientific models and modeling are summarized. Then, 39 experts and 8 researchers are chosen to do the three-stage questionnaire and interview, and 1576 students are selected from junior high school and 1625 students from senior high school to do the empirical study. The classification and cognitive level of physics models perceived by high school students have been founded as well as the influence on schools and regions. Finally, regression analysis on the model construction process of students is conducted. The result shows the cognitive level of scientific models held by students, appeared in Chinese national curriculum standards and national examination requirements are equivalent, but there are also some differences among students' learning, curriculum standards and examination requirements. A specific classification of the models based on the comprehensive understanding systems is conducted, and the impact on learning among different schools and regions and inherent relationship on the cognitive level of physics models are founded.*

Key words: *cognitive level, modeling mechanism, physics model, scientific model.*

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Introduction

Scientific model has been advocated as a central role of teaching in science education reform all over the world, with the critical method to achieve one of the goals of science education is to promote scientific models and modeling. Model and modeling is the basis of cognition and scientific inquiry, which has played a catalytic role in students' learning and cognitive science. Firstly, the model helps learners to learn scientific knowledge and promotes them to understand the scientific concepts and laws. Secondly, the model helps learners to understand the nature of science, and understand the model characteristics, relationship of model and entity, and prediction function by modeling. Finally, the model helps students to do science, and participates in the inquiry process to obtain the comprehensive understanding and skills (Wang, Guo, & Jou, 2015). However, much research (e.g. Schuchardt, & Schunn, 2016; Dori, & Kaberman, 2012; Etkina, Warren, & Gentile, 2006; Tuminaro, &Redish, 2007) shows that there are differences in the cognitive level of scientific model, while the modeling process is also more personalized. Since the Chinese research on scientific models is mainly about physics curriculum and focused on its teaching discussion by searching the literatures on China National Knowledge Infrastructure (CNKI), the research on the physics models and its modeling mechanism are mainly conducted in this paper.

Scientific model has three characteristics of descriptive, explanatory and predictive, which are also the three levels of model cognition and play a positive role in scientific research. The element of scientific method is the formation and testing on models, with understanding of model and modeling capabilities in teaching served as focused part (Hestenes, 2010). International science education research has transformed the view from the conceptual change to the model construction. At the same time, they have reformed the former teaching philosophy of scientific method since twentieth Century, and take science learning as the process of using evidence development and interpretation, revision and test model. Model and modeling are based on the research of conceptual change. The study on modeling starts on Piaget's theory of children development and Kuhn's theory of scientific development. Follow-up researchers-Rea-Ramirez , Clement & Nunez-Oviedo, 2008-believe that Piaget's theory is not good enough to explore the concept of transition by using the mental models, because it does not take emotional factors, role of social learning and learning environment into consideration. Research on conceptual change overly emphasized the changing and replacing, rather than amending, and many studies on conceptual change do not explain how the dialogue between teachers and students affects the science learning, which lacks a clear mechanism to explain the modeling process.

Literature Review

There are two representative divisions of scientific model based on the characteristics and function. Buckley and Boulter (2000) find that there are six ways to characterize the models, which are specific model, language model, visual model, mathematical model and motion model. Harrison and Treagust (2000) propose that the model could be divided into four categories of instructional model, comprehensive understanding model, descriptive model and personalized model. Chinese physics teaching materials of high school divide the model into objective model, conditional model and process model. For example, the particle is the objective model, while smooth surface and the uniform motion are the conditional model and the process model. Chinese physics teaching materials of university classify the model into material model and ideological model, the former, also known as the entity model, such as a spring vibrator, a slit, and the latter also known as the abstract model, such as an ideal conductor, insulator and so on. Based on the space form, the model can be divided into entity models (e.g. spring oscillator), spatial models (e.g. the uniform magnetic field), motional models (e.g. free fall) and the ideal experimental model (e.g. ideal experiment of inclined plane).

Modeling is the process for scientists to establish a scientific theory or solve problems, or for the students to develop the scientific comprehensive understanding, and it could be divided into two phases, called the modeling and the operation of model. Hestenes (1987) suggested that there are four phases of the modeling process, called description (description of the basic variables, development of situation, interaction and characteristics), formalization (using the law and the interaction to form the equation), derivation (depicting a different meaning or form of the model) and validity (considering empirical assessment of branch model). Halloun (1996) proposed that there are five steps to solve the process of modeling, called model selection, model construction, model validity, model analysis, and model deployment. We always ignored the role of validity and deployment in teaching, and the better way to improve them is the interaction and controversy. Halloun (2006) proposed the theory of structured learning cycle consisted of exploration, model adduction, model formulation, model deployment and paradigmatic synthesis. There are different standards on the classification criteria of physics model. The Western countries, mostly from the perspective of the system and the philosophy of science, they focus on the level of individual, interaction and system, and Chinese always divide the model in the perspective of subjects.

Grosslight, Unger and Jay (1991) studied the model of cognitive level by comparing the difference between experts and novices. After comparing the cognitive ability on 7th grade, 11th grade students and experts, they divided the cognitive level into three dimensions, which are entity, between the entity and abstract, abstract. The abstract means that they have the conception of model development and testing, at the same time, they could also explain and predict phenomena. They found that only the experts could get the third dimension, the students of 7th grade mainly on the first dimension, and the students of 11th grade might reach the first and second dimensions. Some students think that model is only a replica of the real thing, or they think scientific phenomenon could only be explained through a model, and the model in the textbook is the fact. Although students can understand the multidimensional characterization, the modification and the description of models, they rarely know the higher level of interpretation, inspection and prediction (Chittleborough, 2005; Treagust et al, 2004).

There are research findings from different subject domains, such as physics, chemistry, earth science and biology that external simulations with models enhance students' mental simulations in related topics (Buckley, 2000; Clement, Zietsman, & Monaghan, 2005; Russell & Kozma, 2005). Furthermore, evidence shows that when models in multiple forms of representation are presented in an appropriate manner, it fosters effective learning (Adadan, Irving, & Trundle, 2009; Ainsworth, 2008; Tsui & Treagust, 2003). Modeling Theory has been developed with the purpose of constructing the real world, and the main objective of the design of curriculum and instruction should be therefore to teach the modeling. If cognition in science is an extension of common sense, then the structure of models in science should reflect the structure of cognition in general. Mental models are private constructions in the mind of an individual, which is the reaction of the physical world. They can be elevated to conceptual models

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by encoding model structure in symbols that activate the individual's mental model and corresponding mental models in other minds (Hestenes, 2006). Thus, modeling should be the "main objective of science instruction" because it is how science is done, and Modeling should be an effective pedagogy because it is congruent with human (Cabot, 2008). The Modeling Cycle has been designed specifically to help promote conceptual change by creating an environment in which student misconceptions can be confronted and then resolved via a series of carefully structured experiences and dialogues (Wells, Hestenes & Swackhamer, 1995). Results and observations from researches described above established the need to create a modeling-based teaching and learning environment to facilitate students' cognitive development and modeling mechanism. How models and modeling works in different socio-cultural context engender the students' cognitive identification on model-based teaching, so as to find the intrinsic mechanism of modeling process of eastern students. In addition to providing teachers with ideas on modeling methods in the context of eastern culture, other benefits resulting from Chinese students' perception of models and modeling mechanism must also be emphasized.

Research Methodology

General Background of Research

In summary, the scientific model and modeling become the focused concern in the field of international science education. Scientific model is the prototype reproduction according to the specific purpose on scientific research, and modeling is the basis of comprehensive understanding, scientific inquiry and problem solving. According to the discipline, scientific model can be divided into physics model, chemistry model, biology model and mathematical model. In account of the research progress on model of cognitive level and the aspect of the modeling, the investigations around the two aspects are conducted. Three research questions were raised:

1. What's the classification of physics model in Chinese high schools?
2. What would be the cognitive level of students' perceptions of physics models in Chinese high schools?
3. What is the modeling mechanism of students' perceptions of physics modeling in Chinese high schools?

A subsequent mixed research method study by three-stage textual analysis (curriculum standards, teaching materials and test papers), Delphi technique, questionnaires of students' modeling cognition and focus-group interviews are conducted from Jan. 2014 to Feb. 2015 in 24 Beijing high schools. Finally, Students' perceptions of physics models and their modeling mechanism are studied.

Sample Selection

A subsequent mixed research method is used to study in this paper. In the stage of qualitative study, thirty-nine experts are chosen, including thirty-one high school physics teachers (14 in junior high school and 17 in senior high school) and eight researchers (4 in university and 4 in teaching institution). The students from four regions of Beijing (Haidian, Chaoyang, Shijingshan, Yanqing) are asked to finish the questionnaires, and one or two excellent schools and general schools of junior high schools and senior high schools in each region are respectively selected, with one or two physics teachers, who have more than 6 years of teaching experience in each school. In the stage of quantitative study, the high schools from the same four regions of Beijing, and three junior high schools and three senior high schools are selected which are excellent schools, general schools and low-performing schools are also selected. Two classes from each school and totally 24 schools are selected to join us, including 48 classes, which have 1587 students in junior high schools and 1625 students in senior high schools. The study has a good reliability, with the coefficient of 0.927 for the questionnaires of junior high school students' perception of physics modeling and 0.929 of senior high school. The 3 stages of textual analysis and 3 rounds of Delphi technique ensure the validity of the semi-open questionnaires of students' perception of physics models.

Instrument and Procedures

Firstly, the classification criteria on physics model are determined. Secondly, curriculum standards, textbooks, and the test paper for examination of entrance to senior high school and university are used to find out the typical models of. Then, the Delphi technique is presented according to 3 rounds to analyze the classification and types of the physics models, and the experts evaluate the models and reached consensus on the rating scales of the models in the cognitive level through semi-open questionnaires and focus-group interview. The quantitative evaluation on students, includes self-assessment, peer assessment (randomly selected four students in the same class), teachers' assessment and the score of the last year final examination (changed into five scale), and the average score of the above four kinds of assessment are calculated as the cognitive level of students' perception of physics model. Chinese Curriculum Standard has made clear requirements on the ability level of students, that is, perceptual understanding, comprehensive understanding, rational understanding and application. So the evaluation has five levels of unclear, perceptual understanding, comprehensive understanding, rational understanding and application, rating from 1 to 5. According to the statistical results, a descriptive analysis is conducted to compare students' average results, curriculum standard and examination requirements. Significance levels of schools and regions on students' average results are analyzed through T-test study and the regression is used to explore the modeling mechanism.

Data Analysis

Firstly, the models in Chinese national curriculum standard are analyzed, and there are 7 models in junior high school (2 simulated physics models, 5 idealized physics models) and 14 models in senior high school (3 simulated physics models, 11 idealized physical models). The models in Chinese national curriculum standard are quite simple, and the number of idealized physics models is a little more than simulated models. Secondly, the models in the Chinese popular physics textbooks with the version of People Education Press are analyzed. There are 25 models in junior high school textbooks (5 simulated physics models, 20 idealized physical models) and 53 models in senior high school textbooks (7 simulated physics models, 46 idealized physics models). It shows that models learning are consistent with cognitive development and life experience. Thirdly, the models of national examinations of entrance to high school and university are analyzed. There are 18 models in high school entrance exam with 3 simulated physics models and 15 idealized physics models (2 entity models, conditional models and 10 process models) from 2009 to 2013. From 2011, the high school entrance exam appears a simulated physics model, involving electronic solenoid magnetic field, simulation thermal motion of molecules and simulated gravity. It means that the exam paid more attention to the idealized physics models. Idealized physics models are quite more in the high school entrance exam, but the exam topics are relatively fixed. Higher frequency models are lever and pulleys in the entity model, which are definitely being tested in the last five years. Higher frequency models in junior high schools are ideal meter and power, regardless of the weight of rope and friction of conditional models, linear propagation of light, reflection and refraction of light, uniform linear motion, change of state, convex lens and plane mirror imaging, electromagnetic induction, molecular heat movement etc. of process models. While, there are 30 models in high school entrance exam with 3 simulated physics models and 27 idealized physics models (4 entity models, 10 conditional models and 15 process models) from 2009 to 2013. The topics of simulated physics models are relatively fixed, of which particle and point charge appeared every year in the last five year examination. Higher frequency conditional models in senior high schools tested by the university entrance examination are uniform electric field and magnetic field, and uniform circular motion, projectile motion, uniformly accelerated motion, and collision of process models.

Through the three stages of textual analysis and selecting the union of physics models based on the classification standard, 22 models in junior high schools and 36 models in senior high schools have been found, and the semi-opened questionnaire by the technique of Delphi is designed. In the first round of experts' questionnaire, 8 models in 22 of junior high schools and 10 models in 36 of senior high schools have a great debate. Then the second round of experts' questionnaire and focus-group interview are conducted, deleting the molecular arrangement, the change of state, thermal transmission, molecular thermodynamic movement, friction electrification, electromagnetic induction, floating objects, retained ideal power and meter in junior high school. As for senior high school, Quark model, pure electric resistance, pure capacitance, pure inductance, mechanics, conservative force system, electromagnetic induction, molecular thermal motion and nuclear decay are deleted, and changing the infinite length straight wire into straight wire. The reasons for deleting are less used in teaching, out of the scope of teaching, complex process, etc. After the third round of discussing on the controversial models, the experts reach the correct response through consensus. Finally, the 42 models are established to study, which are presented in table 1.

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Table 1. Classification of physics models in high school based on the qualitative study.

	Simulated Physics Model	Idealized Physics Model		
		Entity Model	Conditional Model	Process Model
Junior High School (15)	Atomic structure	Point Light	Ideal power and meter	Liner propagation of light
	Magnetic wire	Plane mirror	Smooth plane and bevel	Reflection and refraction of light
	Electronic solenoid magnetic field	Pure resistance		
		Lever	Without weight of rope and friction	Convex imaging
		Pulleys and pulley system		Uniform motion
Senior High School (27)	Electric field lines	Particle	Straight wire	Uniformly accelerated motion
	Equipotential surface	Point charge	Uniform electric field and magnetic field	Free fall
	Magnetic induction line	Tested charge		Projectile motion
	Rutherford atomic nucleus structure	Ideal Gas	Plane mirror and thin lens	Uniform circular motion
		Simple pendulum		Simple harmonic motion
	Thomson's atomic model	Point Light	Parallel light	Liner propagation of light
	Bohr's atomic model	Spring oscillator		Reflection and refraction of light
				Interference and Diffraction of light
				Dispersion and polarization of light
				Collision

Results of Research

The Cognitive Analysis of Students' Perception of Physics Models in Junior High School

The cognitive status of students in junior high school is at the level of comprehensive understanding and rational understanding, and the low-level of neither perceptual understanding nor high-level application are referred (table 2). The four dimensions of cognitive level are perceptual understanding-PU, comprehensive understanding-CU, rational understanding-RU and application AN, as shown in table 2. In general, students in junior high school are at upper middle level, and their cognitive level of atomic structure, magnetic induction line, electronic solenoid magnetic field and ideal meter are in the dimension of comprehensive understanding. The cognitive level of atomic structure, reflection and refraction of light and convex imaging held by students are higher than the curriculum standard. Atomic structure is combined with chemistry of junior high school, and students begin to learn chemistry from grade 9, which may get better coordination with physics. Reflection and refraction of light are in the optical part of grade 8, which has significant impact on daily life, and students' learning interest is relatively high because of their beginning of studying physics. Convex imaging involves more hands-on experiment, which is tested often in the entrance examination to senior high school, and that's the reason why cognitive level of students is relatively high. The cognitive level of magnetic induction line, electronic solenoid magnetic field, and rectilinear propagation of light are obviously lower than the curriculum standards. Magnetic induction line and electronic solenoid magnetic field belong to the grade 9, which are difficult and abstract, need more space imagination, and students have cognitive barriers for this field in the understanding of the three-dimensional space structure. The difficulty of rectilinear propagation of light is the understanding of the propagation conditions, which are homogeneous medium, and students often ignore when dealing with problems.

Table 2. The cognitive analysis of junior high school students' perception of physics models.

Category	Models	Average	Level	Curriculum Standard	Examination Explanation	Difference on	
						Schools	Region
Simulated physics model	Atomic structure	3.19	CU	PU	——	.001**	.022*
	Magnetic induction line	3.05	CU	RU	PU, CU	.001**	——
	Electric solenoid magnetic field	3.08	CU	RU	——	.003**	——
Idealized entity model	Point Light	2.88	CU	——	——	.020*	.032*
	Plane mirror	3.78	RU	——	——	.003**	.000**
	Pure	3.80	RU	——	——	.004**	.001**
	Lever	3.88	RU	——	PU, CU	.001**	.001**
	Pulley and it's system	3.87	CU	——	PU, CU	.011*	.022*
Idealized conditional model	Ideal power and meter	3.37	CU	——	——	.004**	.002**
	Smooth plane and bevel	3.63	RU	——	——	——	——
	Without weight of rope and friction	3.75	RU	——	——	.000**	.006**
Idealized process model	Rectilinear propagation of light	4.09	RU	AN	PU, CU	.015*	.007**
	Reflection and refraction of light	4.01	RU	PU	PU, CU	.008**	.003**
	Convex imaging	3.85	RU	PU	PU, CU	——	.006**
	Uniform motion	4.10	RU	——	——	.006**	.002**

*** p <.01, * p <.05.*

Students' average scores of three kinds of high schools (excellent school, general school and low-performing school) and four regions of Beijing (Haidian, Chaoyang, Shijingshan, Yanqing) have been analyzed respectively in the t-test. 13 in 15 models in junior high school have significant differences by the factor of school except the smooth plane and inclined plane, and convex imaging. 12 physics models in junior high school have significant differences by regions except smooth plane and inclined plane, magnetic induction line, and magnetic field of electrified solenoid. Students have a better understanding of convex lens imaging, according to the analysis of cognitive level, which means their cognitive level is higher than the curriculum standard. Since it is more complex to understand magnetic induction line and electric solenoid magnetic field, the students' cognitive level is obviously lower than the curriculum standard. Smooth plane and inclined plane are easiest to understand, so they are not affected by schools. The students' cognitive level of convex imaging is influenced by schools, but not affected by the region. Magnetic induction lines and electric solenoid magnetic field are more difficult, so students from excellent schools and general schools both have difficulties in learning, therefore no difference existed among schools, but there are differences among regions. In a word, there are differences among different regions, but it is not necessarily related to school type, this may be related to specific research characteristics of regions and counties.

The Cognitive Analysis of Students' Perception of Physics Models in Senior High School

Physics model of senior high school students' cognitive level also involves the perceptions of three dimensions, which are perceptual understanding, rational understanding and comprehensive understanding. High school students' cognitive level in particle, point charge, uniform variable linear motion, interference and diffraction of light, dispersion and polarization of light, collision, and others is higher than the curriculum standard. Particle and point charge are idealized model, which play an important role in high school physics. It is explicitly put forward by curriculum standard that "cultivating ideal scientific thinking for students by studying particle and point charge", deliberately designed in teaching materials and taught carefully by teachers. As for uniformly accelerated motion, the process of students' cognitive level is also in a high level. It is one of the simplest variable motions, based on the study of displacement, frame of reference coordinate system to investigate ideal processes, giving conditions to the other complex motions. Students' cognitive level of uniformly accelerated motion is higher because of its fundamental position, and their cognitive level of the model on the phenomenon of light (interference, diffraction and polarization, dispersion, etc.)

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is higher than that of curriculum standard, but not so apparently. As for collision process model, an ideal model with high practicability, curriculum standard requirements are relatively low.

Senior high school students' cognitive level of electric field lines, magnetic induction lines, reflection and refraction of light is lower than the Chinese national curriculum standard. Electric field and magnetic induction lines are virtual figure lines used to describe the abstract physics concept, which can crystallize and visualize physics concept, but it is a virtual figure line requiring students to have a certain space thinking ability, and high requirements to the solid geometry, so the students' cognitive level is on the low standard. Although the junior high school students have learnt the reflection and refraction of light, it needs further enhancement, and index of refraction is an unfamiliar and abstract concept for students, so it is below the curriculum standard.

By T-test, students in different schools and regions have different cognitive level on the physics models, and only in the 5 models of Bohr atom model, point light, straight wire, flat mirror and thin lens, parallel light exist no school and region differences. Some models also have differences among schools and regions, the model influenced by the schools but not regions are as follows: Thomson "date cake" model and interference and diffraction of light. People experienced the process of Thomson, Rutherford and Bohr proposing the model and the cognitive level of the former, and secondary schools have different opinions on the typical three molecular models. The cognitive level of students' perceptions of interference and diffraction of light are higher than that of curriculum standard, but because of the difficulty of the model, the differences existed between excellent and general schools. The models influenced by the regions, but not schools are as follows: dispersion and polarization of light and the ideal gas, and it might because that there is difference in the teaching materials analysis of the models and relevant lecture requirements of different regions in Beijing. Students' cognitive level of excellent school is generally higher than the general school, and of economically developed regions is higher than that of the less developed regions, but the cognitive level of the atomic structure of the three models is better for the latter than the former may due to it belong to the simulation of the model, and the cognitive level requirements are low, who do not have attention to the former.

Table 3. The cognitive analysis of senior high school students' perception of physics models.

Category	The models	Average	Level	Curriculum Standard	Exam Explanation	Difference on	
						Schools	Region
Simulated physics model	Electric field lines	3.90	RU	AN	RU, AN	.001**	.001**
	Equipotential surface	3.78	RU	—	RU, AN	.001**	.001**
	Magnetic induction line	4.09	RU	AN	PU, CU	.032*	.031*
	Rutherford's atomic model	2.48	PU	PU	—	.001**	.018*
	Thomson's atomic model	2.40	PU	PU	—	.014*	—
	Bohr's atomic model	2.34	PU	PU	—	—	—
Idealized entity model	Particle	3.85	RU	CU	PU, CU	.014*	.010*
	Point charge	3.92	RU	PU	PU, CU	.0001**	.0001**
	Tested charge	3.74	RU	—	PU, CU	.0001**	.0001**
	Ideal Gas	2.28	PU	PU	—	—	.041*
	Simple pendulum	3.70	RU	—	PU, CU	.012*	.008**
	Point Light	2.71	CU	—	—	—	—
	Spring oscillator	3.66	RU	—	—	.003**	.002**
Idealized conditional model	Straight Wire	3.51	RU	—	—	—	—
	Uniform electric field and magnetic field	4.01	RU	RU	RU, AN	.0001**	.0001**
	Plane mirror and thin lens	3.00	CU	—	—	—	—
	Parallel light	3.28	CU	—	—	—	—

Category	The models	Average	Level	Curriculum Standard	Exam Explanation	Difference on	
						Schools	Region
Idealized process model	Uniformly accelerated motion	4.22	RU	PU	RU, AN	.002**	.013*
	Free fall	4.20	RU	——	RU, AN	.0001**	.000**
	Projectile motion	4.19	RU	——	RU, AN	.0001**	.000**
	Uniform circular motion	4.01	RU	——	RU, AN	.001**	.000**
	Simple harmonic motion	3.76	RU	RU	RU, AN	.044*	.000**
	Linear propagation of light	3.63	RU	——	——	.037*	.003**
	Reflection and refraction of light	3.35	CU	RU	RU, AN	.003**	.003**
	Interference and diffraction of light	3.11	CU	PU	——	.031*	——
	Dispersion and polarization of light	2.92	CU	PU	PU, CU	——	.039*
	Collision	3.44	CU	PU	RU, AN	.0001**	.0001**

*** $p<.01$, * $p<.05$.*

Regression Analysis of Students' Perception of Physics Modeling Process

Take the correlation and classification into consideration, the modeling mechanism by regression analysis on SPSS 19.0 is investigated. In this part, the modeling mechanism of electromagnetic, optical and kinematic are studied. There are two models of the magnetic induction line and electric solenoid magnetic field which belong to simulated physics model, and we conducted regression analysis on the data of the two groups. It shows that they have a strong correlation, and the data of electric solenoid magnetic field is 0.842, which means that the cognition of magnetic induction line could explain the model of electric solenoid magnetic field, and the explanation ability has 84.2% probability. The regression coefficient is 0.918(the table 5), which means that the model of magnetic induction line could predict the model of electric solenoid magnetic field in the degree of 91.8%. Therefore, it could predict students' cognitive level of electric solenoid magnetic field from their learning of magnetic induction line.

Table 4. The explanation ability data of regression analysis on electromagnetic in junior high school.

R	R^2	Adjusted R^2	Estimated standard error	Changed statistics				
				variable of R^2	F variance	Numerator freedom	Denominator freedom	Significance p
.918a	.842	.842	.6185	.842	1532.48	1	1287	.0001

Table 5. The regression coefficient statistics of electromagnetic in junior high school.

	Non normalization factor		Normalization factor	t	Significance
	B	Standard error	Beta		
(constant)	.264	.081		3.267	.001
Magnetic induction line	.925	.024	.918	39.147	.0001

a. Dependent Variable: the magnetic of electric solenoid magnetic field.

The regression analysis on senior high school magnetic module which has three models is investigated. The cognitive level of electric field line to explain magnetic induction line is 0.828, and the equipotent surface of the magnetic induction line is only 0.027, which implicate the construction of magnetic induction line model mostly influenced by electric field line, with the regression coefficients of 0.57 and 0.346. The cognitive path for these three models as shown in figure 1, the linear with arrow is the regression coefficient, and the curve with arrow is the relational coefficient. Electric field line and equipotent surface have a closer relationship with a relational

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coefficient of 0.57, and the influence of the model of equipotential surfaces to electric field lines if 0.364, so the cognitive level of electric field lines has a principle influence on magnetic induction line. The result helps teachers to know the mechanism of students' cognitive mechanism of the electromagnetism module, and makes it clear that the crucial part to construct the electromagnetism module is the model of electric field line.

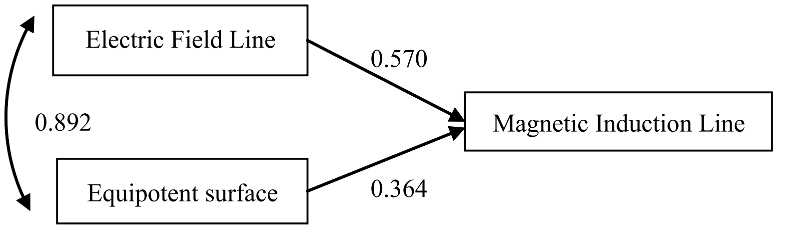

Figure1: Modeling path of electromagnetism module in senior high school.

The models of optics module in junior high school include the propagation of light, the reflection and refraction of light and convex imaging, and it includes the propagation of light, the reflected and refractive of light, interference and diffraction of light and the dispersion and polarization of light in high school. The modeling path of students in junior high school is shown in the figure 2 by conducting regression analysis. In this modeling path, the explanatory ability of the reflected and refractive of light is powerful (0.674), and 0.037 for propagation of light. The regression coefficient of reflection and refraction of light is also great whose value is 0.496 and 0.378 for propagation of light. It is clear that the cognitive level of propagation of light and the reflected and refractive of light have effect on the construction of convex imaging model, in which the reflected and refractive of light has the most influence of 67.4% explanatory ability. Meanwhile, there is great correlative whose propagation of light and the reflection and refraction of light, and the correlation coefficient is 0.861, whose construction has significant correlation.

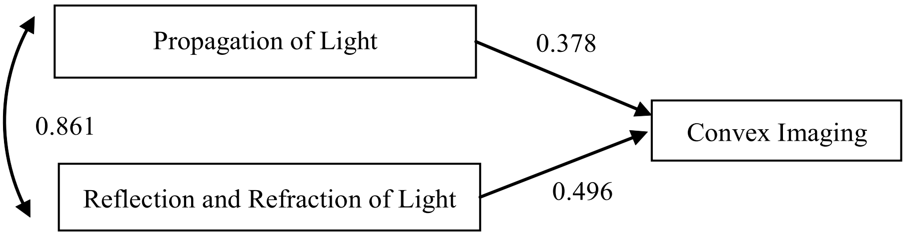

Figure 2: Modeling path of optics module in junior high school.

Similarly, optic module of high school consists of four parts, which are linear propagation of light, reflection and refraction of light, interference and diffraction of light, and dispersion and polarization of light, and we took them into the path analysis of cognitive relationship, as shown in Figure 3. The linear propagation of light is the basis for students to understand the model, which has the biggest impact on reflection and refraction of light followed by light interference and diffraction linear propagation of light and reflection and refractive of light influence of optical interference, diffraction model construction, but the latter effect is relatively large (0.828). Reflection and refraction of light has the greatest impact on the optical interference and diffraction model. Students' understanding is developed like a chain, and the knowledge of optical module presented to spiral. From the path graph, the main construction of their optical module is light reflection and refraction-optical interference and diffraction-dispersion and polarization of light, the cognitive process sequence of which is in accordance with the teaching materials. At the same time, reflection and refraction of light is the source of the cognitive chain, and teachers in the teaching process should pay attention to the modeling of the source model, understanding the students' mental models. Besides, the value of standardized regression coefficient of students' understanding between linear propagation of light and the polarization and dispersion of optic is negative, indicating that cognitive effects, that is, the light polarization and dispersion affect the linear propagation of light, but the degree is not very high.

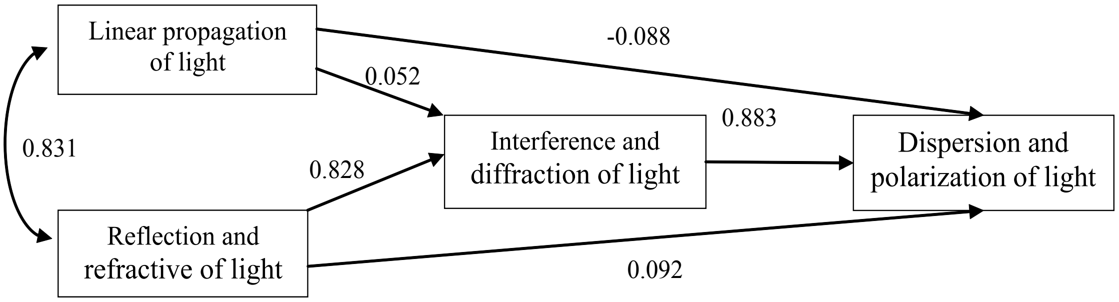

Figure 3: Modeling path of optics module in senior high school.

Kinematics is both the important and difficult topics in high schools, and the main models of kinematics belong to idealized process model, consisting of linear propagation of light, reflection and refraction of light, interference and diffraction of light, and dispersion and polarization of light. Through the same method, the modeling mechanism of kinematics is found, and the cognitive of path is "uniformly accelerated motion-free fall-projectile motion-uniform circular motion-simple harmonic motion", which is also in accordance with the teaching materials. It indicates that the teaching sequence and knowledge development have effect on students' learning.

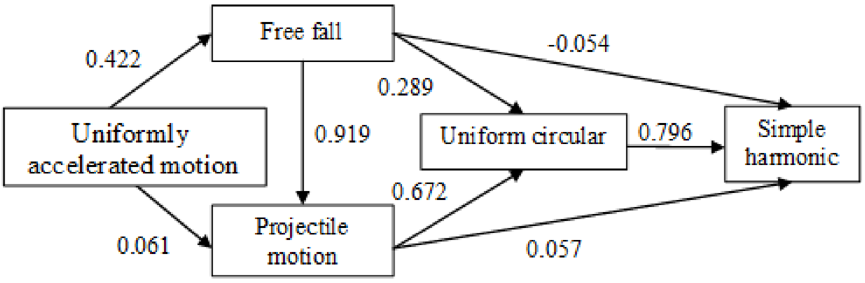

Figure 4: Modeling path of kinematics module in senior high school.

Discussion

The empirically based findings mentioned above conform to the theoretically-based assumptions and fit the objectives of Chinese students' perceptions of physics modeling in general and the aims of the study of Chinese students' modeling mechanism in particular. What is more, the findings of this subsequent mixed method study are in agreement with the research of Modeling Theory. The modeling teaching in science education is also referred as model-based teaching, and it is widely used in the teaching of mathematics, physics, chemistry, biology and geography. It reflects the inquiry process of nature of science and achieves the teaching philosophy of scientific inquiry. In recent years, it proposes the model-based inquiry in science education, because the model and modeling plays an important role in scientific inquiry (Khine & Saleh, 2011). The result shows that average scores of students' perception of physics models, curriculum standard and examination requirements are in the same level. However, there are some differences among them, for example, the models of magnetic induction line, magnetic induction line, propagation of light in junior high school and the models of electric field line, magnetic induction line, reflected and refractive of light in senior high school are lower than the curriculum standard and examination requirements. And the models of atomic structure, reflection and refraction of light, convex imaging in junior high school and the models of particle and point charge, uniform speed linear motion, interference and diffraction of light, and the dispersion and polarization of light and collision in senior high school are higher than the curriculum standard and examination requirements. The life experience is helpful for students to learn and apply these models, and the economic development affects the learning of models. So we should promote learning by narrowing the gap between urban and rural areas, reducing the difference in the school region so that we could achieve a balanced development of educational resources. Different regions of Beijing have their own teaching and investigating activities once a week in the semester, and the dialogue among different regions is urgent, which could be developed by flipping classroom, cloud learning

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environment and so on to share the high quality teaching result and experience.

Model-based inquiry teaching emphasizes raising questions and designing process, conducting the experiment and forming result by communicating. Teachers and students try to reveal the scientific phenomenon, to construct or re construct the models based on the result of inquiry (Oh& Oh, 2011). In a sense, model-based reasoning is the foundation of scientific laws construction, and all of the scientific principles are the nature of constructing and interpreting the date by scientists' using the method of modeling in inquiry way (Wang, & Zhao, 2016), so it plays an important role in developing, using, assessing, and revising the models and relative interpretations, which are also the significant characteristics of students' science education (Passmore, Stewart, & Cartier, 2009). Halloun (2004) proposed five stage of model learning based on the research of Capra, the process of which is exploration, model adduction, model formulation, model deployment and paradigmatic synthesis. Based on this research (van Joolingen's, 2004), the researcher (Oh and Oh, 2011) suggest the five models of teaching conceptual framework, that is, expressive modeling, experimental modeling, evaluative modeling, exploratory modeling and cyclic modeling. This five model educational framework is accepted by international science educators and teachers, and teachers could apply one or more stages. The inherent relationship of cognition between models by regression analysis is also proposed in this study. These relationships could help to discover the rules of students' cognitive process of physics modeling and seek the developmental methods to promote students' conceptual change on the learning of physics models.

Conclusions

This study shows the cognitive level of Chinese students' perception of physics models and its influence on different schools and regions. The modeling mechanism of students' cognitive construction is studied to make the development on physics modeling teaching methods. This will finally lead to the enhancement of research on models and modeling, both in the culture context of Western and the Eastern countries. It has great differences in the teaching of models among different schools and regions in Chinese high schools, and the economic development level affects the learning of models. Chinese national curriculum standard and examination requirements also have an effect on the learning of models. What is more, there is inherent relationship of students' cognitive process, which indicates some regular patterns of physics modeling construction. Learning progress is the core area in the official documents "*A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*" by the United States, and which has received great reaction of theoretical and comparative research. This study could practically testify the cognitive mechanism of students' scientific modeling process to design an appropriate learning path of physics pedagogy, which becomes the crucial part of learning progress to provide us a golden key to open the black box of students' science learning. Subsequent research may utilize large scale quantitative surveys and cognitive neuroscience theory to find the mechanism function of physics modeling to match cognitive theory at the psychological level with neural network theory at the biological level. Further cross-national study could also be conducted to compare students' perception of scientific models in different cultural context, and how these cognitive models affect classroom teaching in different countries.

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