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Analysis on High School Mathematics Teachers' Inquiry Teaching Behaviors: The Perspective of Textbook Use

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Abstract

In order to facilitate teaching approach reforms of high school mathematics, quite many inquiry-related tasks are designed in China high school mathematics textbooks and interspersed in mathematical concepts and propositions formation. To investigate teachers' useage of those inquiry-related tasks, 16 new lessons which inlove 69 iquiry-related tasks of high school mathematics textbooks are collected, and the teaching status of those inquiry-related tasks are analyzed from inquiry subject, inquiry interaction, level of inquiry openness, process skills and adaptation degrees of textbooks. Three conclusions are drawn as follows: teachers prefer to adopt traditional teaching approaches to teach inquiry-related tasks; in the process of teaching, students mainly use basic process skills to fulfill those inquiry-related tasks; most teachers use those inquiry-related tasks without adaptation.

Key words: High school mathematics class; Inquiry teaching behavior; Inquiry-related tasks of textbook; Textbook use

INTRODUCTION

One of objectives of China high school mathematics curriculum reform, which was started in 2003, is to shift the traditional teaching approach that the teacher gives lessons and students are passive listeners, and to raise students' creative consciousness and practical capabilities. For this purpose, "High School Mathematics Curriculum Standards" (Hereinafter referred to as "Curriculum Standards") has underlined mathematics inquiry for many times in the basic curricular concepts, objectives, content standards and implementation suggestions and expressly pointed out in the textbook compilation suggestions: "the textbook should leave ample room to guide students for independent inquiry" (Ministry of Education of the People's Republic of China, 2003). Therefore, the huge difference between high school mathematics textbook of People's Education Press, compiled under the guidance of Curriculum Standards, and Outline Version textbook, is that quite many inquiry-related columns are involved, which are interspersed in the textbook and its appendixes in columns like "Thinking, Inquiring, Observing, Reading & Thinking, Inquiring & Discovering, Applying Information Technology, Practicing Homework" (Xu, 2012; Liu, 2012), and words like "experimenting, inquiring, observing, investigating, communicating, thinking, discussing and thesis writing" appear in descriptions. Moreover, they are always specific problem-solving oriented, and students are required to experience part or all the process of "observing and analyzing mathematical facts, putting forward meaningful mathematical questions, conjecturing and inquiring appropriate mathematical conclusions or rules, and providing explanations or justification" (Ministry of Education of the People's Republic of China, 2003), thus providing essential materials for students to inquire mathematics. It's fair to say that the initiatives in textbook have provided necessary support for the transformation of high school mathematics teaching approaches. However, it is crucial for teachers to use these inquiry-related columns by following the writers' intentions. The author discovers while consulting bibliography that the research on inquiry-related columns in high school mathematics

textbooks (Hereinafter referred to as inquiry-related columns) is mostly concentrated on text analysis. So, do high school mathematics teachers give their students the chance to independently explore inquiry-related columns? This question requires empirical study to answer.

1. METHOD

1.1 Data Collection

By taking the chance of the teaching and researching activities about heterogeneous forms for the same subject in many schools in K city of Yunnan province, 16 new lessons of 16 teachers were collected in 2014-2015 academic year, all of which used People's Education Press's A edition high school mathematics textbook, seven teaching subjects which include 45 inquiry-related columns of the textbook were involved: the Concept of Function (two lessons), Odevity of Function (two lessons), Exponential Function and Its Nature (two lessons), Positional Relationship of Straight Lines in Space (two lessons), Judging Theorem of Straight Line Paralleled with Plane (two lessons), Judging Theorem of Straight Line Vertical with Plane (two lessons), Ellipse and Its Standard Equation (four lessons). The gender ratio of observed teachers was 4:6 (male: female); they were mainly regular college graduates (81.3%), and the rest had a master's degree (18.7%); 50.0% teachers had less than five years' on-the-job experience; 25.0% had 5-10 years' teaching experience, two had 10-20 years' and two had above 20 years' teaching experience, accounting for 12.5% respectively; their professional titles were mainly level one of middle school teachers, accounting for 43.8%, followed by 31.3% of level two, 12.5% of those without professional titles, and 6.3% senior and special class teacher respectively, the number of which was 1.

1.2 Data Analysis

The author finds in classroom observing process that, as for different inquiry-related tasks in the same inquiry-related column, teachers have different ways to teach them. For example, in the elective textbook 2-1, page 38 inquiry-related column in "Ellipse and Its Standard Equation": The student is required to finish two tasks, of which one is ellipse drawing and the other is to abstract the conditions that the moving point meets (Curriculum and Textbook Research Institute, para.7, 2007). In one lesson, the ellipse drawing task is independently completed by students, and the task to abstract the conditions that the moving point meets is fulfilled by teachers heuristic teaching; while in another teacher's lesson, the two tasks are all fulfilled by teachers heuristic teaching. If we use inquiry-related column as analysis unit, the teaching approach difference between these two teachers cannot be distinguished. Therefore, the study takes tasks as analysis units, classifies single task teaching ways of teachers, and inputs SPSS for data analysis. Based on statistics, 77 inquiry-related tasks are involved in these 16 new lessons, 69 are taught by teachers, and the task selection proportion is 89.6%.

1.3 Analysis Framework

The study is focused on inquiry status when inquiry-related tasks are used, so the study refers to inquiry teaching implementation degree evaluation mode built by Chinese researchers (Huang, 2012) and the process skill training framework put forward by SAPA course (Gagne,1967) to build the analysis framework (seen in Table 1) for high school mathematics teachers' use of inquiry-related tasks in classroom teaching.

Table 1
Analysis Framework of High School Mathematics Teachers' Use of Inquiry-Related Tasks in Classroom Teaching

Observing item	Observing point
Inquiry subject	Is the task is inquired by teachers or students?
Inquiry Interaction	How students and teachers are interactive while the task was inquired?
Inquiry openness Level	How is the inquiry room of inquiry-related task while the task was inquired?
Process skill	What process skill do students use to inquiry the task?
Textbook Adaption degree	Do teachers adapt the inquiry-related tasks of the textbook?

2. RESULT

2.1 Inquiry Subject of Inquiry-Related Tasks' Teaching

"Inquiry subject" is the main representation of inquiry teaching and also the core embodiment whether teachers truthfully fulfill the textbook writers' intentions when using inquiry-related tasks. "Scientific Inquiry and National Scientific Education Standard-Teaching and Learning Guide" points out that teachers are expected to throw a question for students to think about when using inquiry in teaching, and then students seek for possible explanations to the question (American National Research Council, 2004). It has pointed out in a profound way that the subject of inquiry is student, not teachers. However, inquiry teaching in nature is a simulative scientific research activity (Jin, 2002). One of the simulative embodiments is that students can be guided when necessary, so the research adopts double subject coding system, and the subjects of inquiry-related tasks classroom teaching are classified into four types: Teacher, Teacher/Students, Students/Teacher, Students. If the "Teacher" is the inquiry subject, it means the task is taught by the teacher, and students don't have any chance to inquire;

in "Teacher/Students" type, it means tasks are taught by the way of questions and answers between teacher and students in the heuristic method, and students play a certain role; in "Students/Teacher" type, students inquire the tasks independently under the assistance of their teacher; in "Students" type, students inquire tasks on their own completely. From "Teacher" type to "Students" type, the students' subject status in the teaching of inquiry-related tasks is increasingly important. According to the classification above, the inquiry subject distribution of 69 inquiry-related tasks taught in 16 class lessons is shown in the following Table 2.

Table 2
Inquiry Subject Distribution in Inquiry-Related Task Teaching

	Teacher	Teacher/ students	Students/ teacher	Students
Frequency	4	45	16	4
Percent (%)	5.8	65.2	23.2	5.8

It can be seen in the Table 2 that the "Teacher/ Students" type inquires the most tasks, 45 (i.e. 65.2%) inquiry-related task teaching is done by teacher's heuristic teaching, the teacher dominates the classroom teaching and inquiry directions, and students are in an assistant status; the "Students/ Teacher" type is ranked in the 2nd place, in which 16 (i.e, 23.3%) inquiry-related tasks are inquired by students under the assistance of their teacher; the "Teacher" type and the "Students" type are involved in four inquiry-related tasks (5.8%) respectively, which is beyond the researcher's expectation. These results may be related to the sampling, but anyway in inquiry-related tasks teaching with only teachers as the inquiry subject is in a relatively small proportion, and it's glad to see that it is a considerable proportion for students as the inquiry subject. However, the task inquiry with teachers as the main subject makes up of 71.0%, which is not satisfactory.

2.2 Inquiry Interaction of Inquiry-Related Tasks' Class Teaching

"Inquiry Interaction" is focused on the interaction ways of the teacher and students in inquiry-related task teaching. By refering to the coding system of Huang He，the study classifies student-teacher interaction into four types: "Teacher Giving Lectures and Students Listening"; "Teacher/Students Interaction"; "Teacher/Students & Students/Students Interaction" (Huang, 2012), "Equal Interaction Between Teacher And Students". The "Teacher Giving Lectures and Students Listening" means the teacher delivers unilaterally by speaking in teaching, and students give feedback by movements and eye contacts or no feedback; "Teacher/Students Interaction" means there is communication and interaction between the teacher and students, but no interaction is among students; "Teacher/ Students & Students/Students Interaction" means students are allowed to learn from and ask questions to each other, but the teacher remains the center of the interaction; "Equal Interaction Between Teacher And Students" means there is interaction between the teacher and students, and among students themselves, and moreover, individuals involved in interaction are equal. "Equal Interaction Between Teacher And Students" is the most ideal inquiry-related task teaching interaction way, and the "Teacher Giving Lectures and Students Listening" is the traditional teaching method. According to the classification above, the statistics about students and the teacher interaction in inquiry-related task teaching in the textbook is seen in the Table 3.

Table 3
Interaction in Inquiry-Related Task Teaching

	Teacher Giving lectures and students listening	Teacher/ students interaction	Teacher/ students & students/ students interaction	Equal interaction between teacher and students
Frequency	3	56	3	7
Percent (%)	4.3	81.2	4.3	10.1

It can be seen in Table 3 that the most frequent inquiry interaction way is the "Teacher/Students Interaction" type, 56 (i.e. 81.2%) inquiry-related tasks are done by verbal communication between the teacher and students, and moreover, in the inquiry process of tasks, students are not given the chance of interactive discussing and communicating, so it is nothing different from traditional class teaching; 3 (i.e. 4.3%) inquiry-related tasks adopt the interaction way of "Teacher Giving Lectures and Students Listening", students are completely passive listeners in the task completion, and no verbal communication is found between the teacher and students or among students; there are altogether 10 (i.e. 14.4%) inquiry-related tasks adopting the teacher and students interaction ("Teacher/ Students & Students/Students Interaction" and "Equal Interaction Between Teacher And Students" types), i.e. "students inquire to acquire mathematical knowledge", to embody the writer's compilation intentions of inquiry-related tasks . It can be seen that in terms of class teaching implementation of inquiry-related tasks, the teacher tends to adopt the traditional classroom interaction way.

2.3 Inquiry Openness Level of Inquiry-related Tasks' Class Teaching

The "Inquiry Openness Level" refers to the room the teacher leaves for students to inquire mathematics independently. The openness level is closely related to essential elements of mathematics inquiry activities. Generally speaking, among four elements in inquiry activities, namely "Question, Evidence, Conclusion and Demonstration", the Question plays the role of orienting the mathematical activity, and as long as the Question is set, Evidence, Demonstration and Conclusion are

basically fixed in a covert way; Demonstration and Conclusion are both related to evidence, and moreover, Evidence and Conclusion are mutually decided so as to have mutual orientation; once the Question, Evidence and Conclusion are seted, the Demonstration is also fixed (Liu, 2012). Therefore, which step students get started from "putting forward Questions→looking for Evidence→exploring Conclusion →carrying out Demonstration" clearly embodies the independent inquiry room of students. This study distinguishes four openness levels of inquiry-related task teaching: "Question Starting Type", "Evidence Starting Type", "Conclusion Starting Type" and "Demonstration Starting Type" respectively. The "Demonstration Starting Type" refers to that students start to inquire from the demonstration step; "Conclusion Starting Type" refers to that students start to inquire from the step of exploring conclusions; the "Evidence Starting Type" refers to that students start to inquire from the step of looking for evidence; the "Question Starting Type" refers to that students are in charge from the question raising. According to the classification above, see the table 4 of statistics about the teacher's inquiry-related task teaching openness level.

Table 4
Distribution of Openness Level of Inquiry-Related Task Teaching

	Demonstration starting type	Conclusion starting type	Evidence starting type	Question starting type	Average openness level
Openness Level	1	2	3	4	
Frequency	0	53	16	0	2.23
Percent（%）	0	76.8	23.2	0	

It can be seen from the Table 4 that 53 (76.8%) out of 69 inquiry-related tasks are "Conclusion Starting Type", so teachers always offer the level two openness space to students, and students start inquiry by seeking for conclusions; the second type is "Evidence Starting Type", and in 16 (23.2%) inquiry-related task teaching, students start their inquiry from seeking for evidences, and then they do further exploration based on their evidences to get the inquiry conclusions; 0 starts from demonstration and question. Therefore, when inquiry-related tasks in the textbook are implemented, the openness levels are concentrated on level 2 and 3, and after weighted average, the average openness level of inquiry-related task class teaching is 2.23, indicating in teaching teachers always leave a certain room of inquiry for students.

2.4 Process Skills Used in Inquiry-Related Tasks' Class Teaching

The so-called skills refer to certain manners of action or intellectual activities which are promoted based on practice, and virtually the skills are the manners of action or operational sequence displayed by people when solving problems with knowledge (Che, 2001). The so-called process skills mean those skills that students need to use in inquiry learning. Based on 13 scientific process skills of SAPA curriculum, we point out there are 16 process skills as follows needed in mathematical inquiry learning: observing, comparing, classifying, measuring, predicting, inferring, using time/space relations, using number, making a chart or graph, identifying and controlling variables, communicating, experimenting, investigating, formulating hypothesis, defining operationally, interpreting data, of which the first ten are basic skills and the later six are integrated process skills. See the following Table 5 for statistics of process skills that the students use in inquiry-related task teaching (Gagne, 1967).

Table 5
Process Skill Distribution in Inquiry-Related Task Teaching

		Frequency	Percent (%)
Basic Process skill	Observing	32	26.0
	Comparing	10	8.1
	Classfying	1	0.8
	Measuring	0	0
	Predicting	1	0.8
	Inferring	29	23.6
	Using time/space relation	21	17.1
	Using number	5	4.1
	Constructing a table and graph	11	8.9
	Communicating	1	0.8
	Controlling variables	1	0.8
	Experimenting	5	4.1
Integrated Process skill	Investigating	0	0
	Formulating hypothesses	6	4.9
	Defining operationally	0	0
	Intepreting data	0	0

Note. Except three inquiry-related tasks in "teachers lecturing and student listening" in teacher-student interaction, in class teaching of all the rest inquiry-related tasks, students express their viewpoints in words, but the communicating objects are different, some of which are students or teachers. According to definition of various process skills in SAPA Curriculum, students apply communicating skills in the inquiry-related task teaching, and the research is focused on the task completion instead of merely class teaching, so students' verbal communication in task teaching which virtually does not help task completion is not counted in the frequency of "communicating" as the process skill.

It can be seen from the table that total frequentcy of process skills' usage by student is 123 in 69 inquiry-related task teaching, of which observing is the most frequently used process skill, its frequency is 32 (accounting for 26.0%); followed by inferring, its frequency is 29 (accounting for 23.6%); Using time/space relations is ranked in the 3rd place, its frequency is

21 (accounting for 17.1%); making a chart or graphing and comparing are ranked in the 4th and 5th place respectively, and their frequencies are respectively 11 and 10 (Proportions are 8.9% and 8.1%); the following one is formulating hypothesis, its frequency is 6 (accounting for 4.9%); the frequency of using numbers and experimenting respectively is 5 (accounting for 4.1%); the four skills, i.e. classifying, predicting, controlling variable and communicating, are only used by students in one inquiry-related task, and none of measuring, investigating, defining operationally and interpreting data is used by students in any task teaching. Generally speaking, basic skills are used for 111 times, accounting for 90.2% of total skill using frequency. In fact when the textbook is compiled, the total skill using frequency involved in 77 inquiry-related tasks is 137, of which basic skill frequency is 121, accounting for 88.3%, and integrated process skill is 16, accounting for 11.7%. It can be seen that the proportion of basic skill using in teaching implementation is 2% higher than that in the textbook.

2.5 Inquiry-Related Task Adaption

This dimension mainly surveys teachers' adaptation of inquiry-related tasks and it is classified into four categories: no adaption, simple development, intensive development and substitute. "No adaptation" means teachers implement tasks, such as materials, task sequence, inquiry way, compilation intention, etc. strictly according to the design of the textbook; "Simple development" means that when using inquiry-related tasks, teachers adjust the task sequence and materials according to certain logic in order to develop inquiry smoothly; "Intensive development" pays attention to if inquiry ways and compilation intention are changed or not; "Substitute" refers to that after understanding the intention of inquiry-related task, the teachers do not get limited by the questions presented by the task, but adopt other questions to complete the teaching intention of the inquiry-related tasks. "No adaption" displays the textbook use style of "depending on textbook", "substitute" shows the textbook use style of "creating textbook", and the rest two reflect the textbooks use style of "adjustment of textbook. In teacher observation teaching, see the following table 6 for statistics about inquiry-related task adaptation.

Table 6
Inquiry-Related Task Adaption Degree Distribution

	No adaptation	Simple development	Intensive development	Substitute
Frequency	40	13	11	5
Percent （%）	58.0	18.8	15.9	7.3

It can be seen from the table that "no adaption" is the most frequent textbook adaption, and in 40(58.0%) inquiry-related tasks teaching, teachers make no changes about the inquiry-related tasks; "simple development" is ranked in the 2nd place, and 13 (i.e. 18.8%) inquiry-related tasks teaching display simple development of textbooks; "intensive development" is ranked in the 3rd place, and 11 inquiry-related tasks (i.e. 15.9%) are involved; "substitute" has the smallest proportion, and five inquiry-related tasks (i.e. 7.3%) are involved. It can be seen that in the face of inquiry-related tasks in the textbook, "dependency on textbook" and "adjusted textbook" textbook use styles are universal for China high schools mathematics teachers. However, totally speaking, teacher's adaptation of textbooks is quite complicated, and this is the embodiment of the new textbook concept in curriculum reforms that textbook is a kind of resources.

CONCLUSSION AND DISCUSSION

It can be seen from inquiry subjects, inquiry interaction and inquiry openness level that 71.0% inquiry-related tasks are mainly accomplished by teachers, 81.2% are inquired in interaction manners of "Teacher/Student interaction", and 76.8% are started from seeking for conclusions. It can be seen that in most inquiry-related task teaching, teachers prefer "questions from teachers and answers from student" way to guide students to complete inquiry-related tasks; students have the chance to get involved in inquiry, but their inquiry room is relatively small; the teachers remain as the center of the class, and the students hold a lower subjectivity position.

Data analysis above only tells us information about teachers' use of inquiry-related tasks in the class teaching, but fails to tell us the reason. In researcher's opinion, it's quite complicated why teachers prefer to adopt traditional teaching ways to teach inquiry-related tasks, on one hand it's possibly because teachers don't understand the intention of these inquiry-related tasks; on the other hand it may be due to some actual circumstances, for example, students are lack of independent inquiry habits and capabilities, teaching time is insufficient, inquiry is time-consuming, etc., such reasons lead to traditional teaching way that the teacher gives lectures and students listen is favored by teachers in inquiry-related task teaching; of course the compilation of inquiry-related task may also be a reason. Just as it is pointed out by Xu Binyan, etc., "mathematical inquiry activities organized by textbooks of China People's Press are mainly question-answering activities, accounting for 86.57% of all activities", and "inquiry-related question-answering activities are mainly calculating and demonstrating mathematical activities (66.53%)"; besides, in textbook compilation, "teamwork is rarely defined in inquiry-related tasks, and only 1.07% clearly requires 'teamwork'" (Xu, 2012). It can be seen that to some extent inquiry-related tasks are similar to traditional mathematical questions, and this absolutely results in traditional tendency of inquiry-related task teaching in terms of inquiry subjects, Inquiry Interaction, Inquiry Openness Level, etc.. As a result, while compilating inquiry-related task，the textbook writers should pay

attention to the selection and presentation of inquiry-related tasks to help teachers to realize and understand the inquiry-related task compilation intention, and effectively improve inquiry effects of inquiry-related task teaching.

According to process skill drillings, over 90% process skills used by students in inquiry-related task teaching are basic skills, and there are very few integrated process skills used. So, process skills used by students are mainly basic process skills, and the reason for this is worth pondering over. This may be related to basic skillss which are emphasized in textbook compilation; or from the teachers' lack of attention to integrated process skills. The class observation proves that inquiry-related tasks that require students to apply integrated process skills are always converted into basic skill tasks by teachers in teaching. For example, when teachers teach "Ellipse and Its Standard Equation", students are responsible for the experimental task of drawing an ellipse, but it turns out teachers are drawing and students are observing, so the integrated process skill of identifying and controlling variables is not trained; there is another possible explanation is that due to the features of time-consuming, high openness level, strong flexibility, etc., the use of integrated process skills is hard to reach in teaching compared with that of the use of basic skills. For this reason, facing the new things in curriculum reform, such as inquiry-related tasks, teachers are expected to be positively engaged in and work hard on improving their capabilities of teaching these inquiry-related tasks, and pushing forward high school mathematics teaching approach reforms, so that the vision of cultivating students' innovative consciousness and practice capabilities can be realized.

Besides, teachers' adaptation of 92.7% inquiry-related tasks reflects "dependent" and "adjusted" styles of textbook use. According to class observation, cases of high or low inquiry levels and good or bad inquiry effects are found in different textbook adaption levels. It can be seen that every textbook adaption degree is worth spreading in inquiry-related task teaching, and the key is to embody the concept of inquiry learning .

It can be seen from the analysis above that the research results may serve as certain revelation and reference for textbook compilation and curriculum implementation. Of course the teaching content depth, inquiry teaching evaluation, etc. are not involved in this research, which are deficiencies of this research and also the direction for further research.

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