Research on Questioning Strategies in High School Mathematics Classroom Driven by "Problem Chain" ——Taking "One way Linear Regression Model and Its Applications" as an Example

Yingying Wang & Yanzhi He
Department of mathematics, College of science, Yanbian University, Yanji, China
*Corresponding author email id:yzhe@ybu.edu.cn

Abstract - The implementation of "problem chain" teaching in high school mathematics curriculum is conducive to arousing students' thinking and improving their core mathematical literacy. Currently, there are practical difficulties in the unit teaching of "One variable Linear Regression Model and Its Application" in high school mathematics, such as disjointed teaching design, insufficient student classroom participation, and inadequate teacher guidance. To address these teaching pain points, strategies such as constructing contextualized problem scenarios, strengthening systematic presets of problem chains, and emphasizing thinking guidance can be used to ensure that the problem chain forms a complete closed loop in knowledge construction, method transfer, and thinking advancement, ultimately achieving the transition from knowledge transmission to literacy cultivation.
Keywords - problem chain; High school mathematics; question strategies

I. INTRODUCTION

The new curriculum emphasizes that mathematics education should cultivate students' core competencies through the "three skills", namely, being able to observe the real world with a mathematical perspective, thinking about the real world with mathematical thinking, expressing the real world with mathematical language, and improving students' problem-solving abilities on this basis. At the same time, artificial intelligence is advancing rapidly in today's era, and AI represented by deep seek is moving towards universality. It is crucial to cultivate students' critical thinking skills. Students should be encouraged to think independently, examine problems from multiple perspectives and dialectically in specific situations, have their own thinking and judgment, maintain composure, be logically rigorous and organized, not blindly follow authority, and not blindly follow others' opinions. Under such circumstances and requirements, the traditional approach of "learning first, solving problems later", "teachers lecturing, students listening", or fragmented and illogical questioning is no longer applicable. Therefore, it is of practical significance to carefully design a logical and hierarchical "problem chain" based on students' cognitive level, using problems to drive students to learn efficiently, explore independently, exercise divergent thinking, cultivate questioning awareness, and directly participate in the generation of experiential knowledge.

II. Survey on the Teaching Status of Univariate Linear Regression Model and Its Application

A. *Implementation of Investigation.*

In order to understand the current situation of high school mathematics classroom teaching driven by the "problem chain", this article takes the "univariate linear regression model and its application" as the starting point for investigation and analysis. During the teaching practice period, a questionnaire survey was conducted in Yanji City Middle School as shown in Table 1. A questionnaire survey was randomly selected from the senior year of a high school in Yanji City, and 160 questionnaires were distributed. After sorting and analysis, 9 questionnaires were identified as invalid and 151 questionnaires were valid. At the same time, interviews were conducted with mathematics frontline teachers in the school during teaching practice. A total of 6 teachers were interviewed, including 2 teachers with over 15 years of teaching experience, 2 teachers with 5-15 years of teaching experience, and 2 teachers with 3-5 years of teaching experience. The age structure was appropriate.

B. *Student Survey Results.*

The survey questionnaire on teaching effectiveness based on the "problem chain" univariate linear regression model and its application can be divided into 4 primary dimensions and 12 secondary dimensions. The specific division basis and question distribution are shown in Table 2. The scoring adopts a 5-point scale, where 1 point represents "very inconsistent", 2 points represents "relatively inconsistent", 3 points correspond to "generally consistent", 4 points correspond to "relatively consistent", and 5 points represent the highest degree of "very consistent". This questionnaire consists of 16 questions, of which 14 are positive scoring and 2 are reverse scoring. In order to unify the analysis direction, the reverse question data was transformed into positive ones in the study.

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Table 1 Classification Basis and Test Question Distribution

First level dimension	Secondary dimension	Corresponding test questions
Teaching Content Design	Clear concept explanation	6. 15
	Knowledge Integration Design	3
Student Understanding and Application	Mastery of core concepts	4. 5, 12
	Practical Problem Solving	7
Problem Chain Design and Implementation	Logical coherence	8. 16
	Gradient difficulty design	10
	Open ended questions	11
Classroom interaction and participation	Frequency of teacher-student interaction	2. 9
	Effectiveness of group collaboration	1. 13
	Sense of achievement in learning	14

To verify the validity of the questionnaire data, the reliability analysis module of SPSS was used to evaluate the internal consistency of the questionnaire using the Cronbach alpha coefficient. The results showed that the overall alpha coefficient value was 0.913, indicating excellent reliability of the questionnaire and fully meeting the needs for further analysis.

Table 2 Reliability statistics of Cronbach

Clone Bach Alpha	Based on standardized items Clone Bach Alpha	Number of items
0.913	0.935	16

In order to verify the validity of the questionnaire data, this test paper used KMO value and Bartlett's sphericity test value, and conducted validity analysis using SPSS software. The results are shown in the table below. The KMO value of this test paper is 0.864, and the significance level is less than 0.001, indicating that the data is very suitable for information extraction.

Table 3 KMO and Bartlett tests

KMO sampling Appropriateness quantity		0.864
bartlett Sphericity test	Approximate chi square	2089.29
	freedom	187
	significance	0.000

Table 4 Descriptive Analysis

Analysis Dimension	Corresponding score	Maximum value	Minimum value	average	standard deviation
Teaching Content and Design	15	15	10	12.34	2.68
Student Understanding and Application	20	20	9	13.89	2.94
Problem Chain Design and Implementation	20	18	6	10.90	2.03
Classroom interaction and participation	25	25	9	14.55	3.79

According to Table 5 above, there are a total of 3 questions in the dimensions of teaching content and design, with a total score of 15 points. The table data shows that the score range for this dimension is 10-15 points, with an average of 12.34 and a standard deviation of 2.68. The relatively concentrated distribution of data indicates that teachers have achieved a high degree of structured presentation of knowledge points, and students' mastery of basic knowledge is universal. It is recommended to maintain the existing teaching strategy while attempting to incorporate interdisciplinary elements to enhance knowledge integration.

There are 4 questions in the dimension of student understanding and application, with a total score of 20 points. The table data shows that the score range for this dimension is 9-20 points, with an average of 13.89 and a standard deviation of 2.94. After analysis, significant individual differences were observed in this dimension. Teachers should implement more layered teaching in the teaching process, add exploration tasks for excellent students, provide basic knowledge training for weak students, and establish a learning community to promote experience transfer.

There are 4 questions in the dimension of problem chain design, with a total score of 20 points. The table data shows that the score range of this dimension is 6-18 points, with an average of 10.90 and a standard deviation of 2.03. The overall average level is not high. After analysis, most classroom teaching is not well carried out in the design and implementation of problem chains. This requires teachers to make adjustments in teaching to avoid giving direct answers. A complete logical chain should be formed through interlocking problem chains, and the difficulty of the questions should be gradually increased. Open ended questions should be introduced appropriately.

There are a total of 5 questions in the dimension of classroom interaction participation, with a total score of 25 points. The table data shows that the score range of this dimension is 9-25 points, with an average of 14.55 and a standard deviation of 3.79. The overall average level is not high, and the fluctuation level is large, indicating that the level of classroom interaction participation is not good enough. There is a phenomenon of continuous silence among students in classroom discussions, which may be due to the lack of clear role division in group discussions. Future teachers need to help students gain a better understanding through finely designed group discussion content and adopt differentiated strategies to enable every student to participate in classroom discussions, thereby enhancing students' enthusiasm and interest in mathematics learning.

C. *Teacher Interview Survey Results.*

The core focus of teacher interviews is on the design concept of problem chain and classroom implementation effects, in order to explore the current situation and challenges of high school mathematics teaching driven by "problem chain", understand students' learning situation, analyze teachers' cognition and practical experience of problem chain driven strategies, and optimize the teaching process. This interview consists of four questions. To ensure the authenticity and effectiveness of the interview results, anonymous recording and written records will be used.

Question 1: How do you design a problem chain when teaching univariate linear regression models and their applications?

Some teachers mentioned that when designing the problem chain of a univariate linear regression model, although they attempted to connect knowledge points, there was a lack of inherent logic between the links. This leads to students passively accepting the calculation steps, failing to understand the entire process logic from data observation to model derivation, lacking open-ended questions, insufficient guidance for critical thinking, worrying about the time-consuming nature of open-ended questions, and affecting teaching progress. Teachers rely more on closed ended questions and design fewer open-ended questions. Most teachers recognize the potential of problem chains, but are limited by class pressure, insufficient lesson preparation resources, and a grasp of students' ability differences. Actual designs are often simplified or fragmented.

Question 2: What impact do you think question chain teaching has on students' questioning ability and depth of knowledge understanding?

Nearly half of the teachers mentioned that a problem chain with clear logic and reasonable gradient can stimulate gifted students to ask extended questions and ask more actively. However, for students with learning difficulties, passive answers are still the main approach, and active questioning is rare. Only a few top students can ask valuable questions, and most students are still accustomed to waiting for teachers to give answers. In the group discussion session, there are many questions asked, but the teacher led session still mainly relies on one-way answers. Most teachers agree that problem-based learning has the potential to enhance students' questioning ability and understanding depth, but due to rough design and group differences, the actual effect has not been fully released. The benefits of eugenics are obvious, while the lack of participation from students with learning difficulties is the core contradiction.

Question 3: Do you focus on cultivating critical thinking in the problem chain? How to guide students from "problem-solving" to "questioning and improvement"?

Most teachers admit to occasionally designing open-ended questions in the question chain to expand students' thinking, but students have long been accustomed to standard answer thinking and have a fear of difficult open-ended questions. They rely on the "question answer" model and lack advanced questioning. At the same time, teachers are concerned that such questions may deviate from the exam focus, take up too much time, be superficial, and lack deep guidance. Teachers tend to control discussion time and ultimately summarize the "standard answers" by teachers.

Question 4: What was the biggest difficulty you encountered during the implementation of problem chain teaching?

Some teachers admit that 'copying textbook examples is simple, but designing a logically coherent and logically reasonable problem chain requires a lot of time and immense pressure'. At the same time, sometimes the questions raised by teachers are like 'throwing them into the air', only a few students can handle it, while others wait to take notes. Most students have insufficient participation, and problem discussions are often delayed due to low student engagement or excessive divergence.

III. CLASSROOM QUESTIONING STRATEGY FOR PROBLEM CHAIN DRIVEN UNIVARIATE LINEAR REGRESSION MODEL AND ITS APPLICATION

The teaching of "problem chain" is a continuous questioning process that delves deeper into students' thinking. It involves setting up a series of progressively linked questions in the zone of proximal development of students' thinking. These questions are closely connected, and students explore and discover multiple, multi-dimensional, and multi-level problems around the interconnected problem scenarios, stimulating their mathematical thinking and enhancing their learning experience. From the perspective of constructivist learning theory, the "problem chain" learning process is a continuous process of knowledge reconstruction. This process is based on students' existing cognitive structures and strengthens the connection with their existing knowledge and abilities. It can help students understand new knowledge, promote knowledge transfer, and facilitate the development of their abilities. Polya's problem-solving theory emphasizes that the formulation of problems should be inspiring, that is, to stimulate students' active thinking and guide them to discover mathematical laws through problems, rather than simply passing on answers. The design of inspiring questions should point towards the thinking path rather than the answer itself, and the questions should imply possible directions for solution but not directly provide methods. Scaffolding style questioning can be used to decompose complex problems into progressive sub problems, activate existing experience, promote problem transformation, and guide exploration of patterns to gradually approach essence through the problem chain.

Taking "One way Linear Regression Model and Its Applications" as an example, teachers can design a layered and progressive "problem chain" to guide students to understand the meaning of the One way Linear Regression Model, the statistical significance of model parameters, the principle of least squares, and the least squares estimation method of model parameters. Students will experience the entire process of systematic data processing, master basic data analysis methods, understand the thinking of data analysis, and learn to apply their knowledge to solve practical problems.

A. *In classroom questioning driven by problem chains, attention should be paid to the design principle of situational orientation.*

For example, when explaining the least squares estimation of parameters in a univariate linear regression model, we can give the example of Gauss predicting the orbital parameters of Ceres. "In 1801, Piazzi first discovered Ceres and subsequently tracked it for 41 consecutive days at the observatory. During this period, a total of 14 sets of observation data were recorded, recording the right ascension and declination coordinates of Ceres on different dates. Due to illness and weather conditions, Piazzi was unable to continue observing it, causing Ceres to temporarily" disappear "from his field of view. Piazzi's observation data is limited in quantity and has a short coverage time, which is not sufficient to directly calculate the complete orbit of the planet. But mathematician Gauss used these data to successfully predict the orbital parameters of Ceres. When German astronomer Obers rediscovered Ceres, its actual position differed from Gauss's prediction by only about 0.5 degrees. ”Introduce the scenario of Gauss finding the laws of celestial motion through limited observational data, set suspense, stimulate students' curiosity, and then delve into the study of correlation coefficients between variables.

B. *In classroom questioning driven by problem chains, attention should be paid to scientifically predetermined design principles.*

When estimating the parameters of the univariate linear regression model around the case of "the relationship between son's height and father's height", present tables and scatter plots to the students and ask questions ①How to find an appropriate straight line that makes the scatter points representing paired sample data closest to this line as a whole. Teachers should prepare questions before class and also anticipate the possible answers that students may give to each question. Fully reflect the "preset and generated" of the classroom, and after summarizing the situations raised by students, teachers can continue to ask questions ②Please continue to conduct feasibility analysis on the above ideas in groups. ③Can we make the number of points distributed on both sides of the straight line basically the same? ④Can we make as many dots as possible fall on this line? ⑤So can we determine a straight line every two points and then calculate the average slope and intercept of the line for all cases, and use the average as the estimated final slope and intercept of the line?

On the basis of intuitive perception of linear correlation, students search for the line that is closest to the overall scatter. Students have already learned about linear correlation and statistics, and can solve difficulties through hard work. Therefore, teachers raise questions layer by layer, fully play the role of students as the main body, guide students to adopt independent thinking and group discussions, brainstorm, and continue to discuss the feasibility of each idea, achieving multi-dimensional exploration of problems and improving the efficiency and quality of the classroom.

C. *In classroom questioning driven by problem chains, attention should be paid to thinking guidance and design principles.*

Encourage students to reflect through questioning. After excluding infeasible solutions, guide students to use distance to characterize these scattered points in the paired sample data that are closest to this line as a whole. ask a question ①How to characterize the 'distance' from a straight line? ②So what is our direct idea? ③So, in analogy to the decomposition of forces in physics, what else can we consider for the distance from a point to a line? ④When the slope of the line is constant, the distance from a point to the line and its vertical and horizontal components are equivalent, right? ⑤Three distances are equivalent. We can choose any one, but which one should we choose? What is the reason for your choice? ⑥The explanatory variable, which is the father's height, can be directly observed. If there is no random error, where should this point fall? ⑦So it is precisely because of the existence of random errors that this point has shifted, and what does this shift refer to? Finally, the teacher made a summary, so we used the vertical distance, also known as the up and down distance, to describe the distance between this point and the straight line, which should be more direct and effective. Therefore, we chose its vertical distance. ⑧Starting from paired sample data, how to use mathematical language to describe "overall, each scatter point is closest to a straight line ⑨Absolute values make calculations inconvenient. Is there any improvement method?

Centered around the case Q of "the relationship between a son's height and his father's height", the teacher presented a complete mathematical process of parameter estimation through layers of heuristic questioning, from intuitively finding a straight line that is close to the overall scatter, to using vertical distance to characterize the "distance" between the scatter and the straight line, to quantitatively characterizing the degree of overall proximity, and finally obtaining parameter estimation. At the same time, in the study of variance in compulsory courses, students have gained certain experience in the transformation and normalization of such problems, which is in line with their zone of proximal development. The entire 'problem chain' encourages students to actively think and experience the process of discovering mathematical laws, allowing them to appreciate the idea of least squares and accumulate experience in data analysis during the learning process. Raise questions within the students' zone of proximal development to enable them to face moderate learning difficulties while maintaining sufficient interest in learning and increasing their participation in mathematical thinking.

D. *In classroom questioning driven by problem chains, attention should be paid to the principle of logical progression design.*

For example, after the new knowledge is taught in this lesson, the teacher can unfold the real-life case of "shoe size and height" in the following levels, which can stimulate students' interest in learning and strengthen their ability to apply statistical thinking and data analysis.

Level 1: Perception issue, may shoe size be related to height? How to use mathematical methods to visually demonstrate the relationship between shoe size and height? After organizing the data into a table, what is the trend of the scatter plot distribution growth?

Level 2: Analyzing the problem, is there a linear correlation between shoe size and height? How to quantify correlation?

Level 3: Modeling problem, if the data follows a linear trend, how to use the least squares method to solve the regression equation? What is the practical significance of slope?

Level 4: Application and Expansion. Does a high correlation coefficient necessarily imply a causal relationship? Provide examples of possible confounding variables. Is the shoe size height relationship consistent between boys and girls?

Based on students' thinking patterns, a hierarchical "problem chain" is set up to guide students in finding solutions to practical problems, helping them gradually learn to think, successfully transfer knowledge and skills, guide students' mathematical thinking activities, reduce thinking difficulty, help students learn to think, and successfully overcome difficulties.

IV. ANALYSIS AND CONCLUSION OF TEACHING EFFECTIVENESS

The understanding of questioning strategies in high school mathematics classrooms cannot be separated from the understanding of mathematics. From a static perspective, mathematics is a rigorous knowledge system. From a dynamic perspective, mathematics is a creative process of exploration and discovery, consisting of a complex of various elements such as problems, methods, language, propositions, and theories. Mathematics not only promotes the development of logical thinking ability, but also enables students to become active participants and explorers in the process of learning mathematics through mathematical activities, truly becoming the masters of learning, and cultivating students' autonomy and innovative spirit. Teachers should deepen students' thinking through questioning, as guides for students' learning of mathematical knowledge rather than indoctrination. The problem progresses layer by layer, making it easier to understand mathematical relationships. Problem chain teaching can effectively enhance classroom participation and enthusiasm, achieving deep learning guided by core competencies for students.

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AUTHORS' PROFILE

First Author
Yingying Wang, 2515156511@qq.com, female, Heilongjiang Province, China, born in May 2002, Studying at Yanbian University, as a first year graduated school student in mathematics education.

Corresponding Author
Yanzhi He, Jilin Province, China, born in June 1966, teaching at Yanbian University, as a professor, and master tutor. Research direction: Theory of mathematics teaching.