# Instructional Design of Trigonometric Functions in High School under the Theory of Deep Learning

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***Abstract***
*Deep learning is a learning method that emphasizes the active participation and development of critical thinking by students. Compared with shallow learning, deep learning emphasizes the deep processing of knowledge by students, actively constructs knowledge to form knowledge structures and internalizes them, and can successfully extract and solve problems. This article studies the instructional design of functions from the perspective of deep learning, investigates the current situation of high school students learning trigonometric functions through a questionnaire survey, analyzes the problems that high school students have in learning trigonometric functions, and finds that students still have obvious shortcomings in knowledge understanding, critical thinking, knowledge integration, and transfer application. This article analyzes the reasons and countermeasures for the problems encountered in the investigation, and explains how to use deep learning theory to guide the instructional design of trigonometric functions.*

***Key words:*** *deep learning, teaching design, trigonometry function*

## Introduction

Deep learning is a kind of learning style that pays attention to the active participation of students and the development of their critical thinking. Deep learning places more emphasis on students' deep processing of knowledge than shallow learning, actively constructing knowledge to form a knowledge structure and internalising it, and being able to extract it successfully to solve problems. Instructional design is based on the requirements of the curriculum standards and the characteristics of the teaching object, the teaching elements of the orderly arrangement, to determine the appropriate teaching programme ideas and plans. It generally includes teaching objectives, teaching difficulties, teaching methods, teaching steps and time allocation. Trigonometric function is one of the basic elementary functions, which is a function with angle as the independent variable and the coordinates of the intersection of the terminal side of the angle corresponding to any angle and the unit circle or its ratio as the dependent variable. Instructional design based on deep learning has great significance for mathematics teaching, and trigonometric function instructional design from the perspective of deep learning can effectively improve teaching efficiency and make students appreciate the real role of mathematical knowledge.

Through the analysis of concepts and practical application, the instructional design of trigonometric functions under the theory of deep learning, students can deeply understand the concepts and image properties of trigonometric functions and their applications in real life, construct the idea of functions, and lay a foundation for further learning of functions in the future.

## 1 Definition of concepts and review of research

### 1.1 On deep learning theory

#### 1.1.1 Origins of deep learning theory

The concept of deep learning can be traced back as far as the 1980s, and deep neural networks began to emerge during this period. The development of modern deep learning is largely attributed to Canadian computer scientist Geoffrey Hinton and his collaborators. The earliest representative paper that explicitly introduced the concept of deep learning was the article by Hinton et al. published in the journal Science in 2006[1]. This article facilitated the development of deep learning in neural networks, signalled the renaissance of deep learning, and laid the foundation for the subsequent rapid development of deep learning. However, this paper refers to deep learning in the field of pedagogy, which does not have a strong correlation with deep learning in neural networks as described above. The concept of deep learning first appeared in the field of pedagogy in 1976 by the University of Gothenburg professors Ference Marton and Roger Saljo jointly published 'On qualitative differences in learning: I-Outcome and process'. In this article, deep learning is a process of pursuing understanding and critically integrating new knowledge with prior knowledge[2].

#### 1.1.2 Research on deep learning theories

Research on deep learning for a long time, the 20th century research scholars mostly regard deep learning as a learning process, following two American scholars Ference Marton and Roger Saljo in the form of experiments to start the study of deep learning, with the continuous advancement of the study, after the 21st century, the researchers more deep learning as a learning outcome. One of the new directions is the interpretation of the Hewlett Foundation (William and Flora Hewlett Fouridation), whose researchers see deep learning as a competency that values the learner's ability to acquire the knowledge needed to solve a problem and to enhance the ability to construct knowledge, including the ability to engage in critical thinking, communication and collaboration, and problem solving[3].

Research on deep learning in China started relatively late. Li Jiahou and He Ling were the first scholars to put forward the definition of deep learning, and they believe that deep learning is a process in which learners use critical thinking to learn new knowledge on the basis of understanding and integrate it into the original cognitive structure. In this process, learners also need to correlate old and new knowledge and be able to use this knowledge to solve practical problems[4]. Guo Hua believes that deep learning has a special significance, which refers to the process in which students actively participate in challenging learning topics under the guidance of teachers, from which they experience success and achieve physical and mental development[5]. Fu Yining summarises the connotation of deep learning from five aspects: first, deep learning is based on internal learning motivation and founded on understanding learning; second, it uses higher-order thinking to learn new knowledge and ideas with a critical perspective; third, deep learning can integrate new and old knowledge, incorporate them into the original cognitive system and construct them; fourth, for different complex situations, learners can creatively problem solving; finally, deep learning can flexibly apply metacognitive strategies to regulate the learning process and reach high levels[6].

Taken together, deep learning in pedagogy is not only about knowledge, but also about developing deep understanding, critical thinking, an enquiring mind and the ability to co-operate with students, helping them to build enduring learning power and skills, and laying a solid foundation for future learning and life.

1.2 On instructional design

1.2.1 Origins of instructional design

Instructional design can be traced back as far as the ancient Greek period. In Ancient Greece, education was considered an important social activity, and instructional design was created to effectively impart knowledge and develop good citizens. The first to study and explore instructional design as a separate field were the ancient Greek philosophers Socrates and Plato. Socrates and Plato believed that instructional design should be a systematic and purposeful process that involves asking questions and guiding students' thinking in order to stimulate their interest in learning and to help them build their own knowledge structures.

1.2.2 Domestic and international research on instructional design

According to foreign scholar Gagne, 'Teaching is a series of events that affects learners in a way that facilitates learning, and teaching system design is the process of systematically planning an teaching system.' Merrill, in his article 'New Declaration on Instructional Design', defines teaching system design as: 'Teaching is a science, and teaching system design is a technology built on the solid foundation of the science of teaching and learning, and thus teaching system design can also be regarded as a science based technology (science based technology) The purpose of teaching is to enable learners to acquire knowledge and skills, and the purpose of teaching system design is to create and develop learning experiences and learning environments that facilitate the acquisition of such knowledge and skills by learners[7].'

Domestic scholars, such as He Kexiang, concluded in the 2nd edition of teaching System Design: 'Teaching system design is a process or procedure that takes the promotion of learners' learning as its fundamental purpose, and uses a systematic approach to convert the principles of learning theory and teaching theory into a specific plan for teaching objectives, teaching content, teaching methods and strategies, and teaching evaluation, and to create an effective teaching and learning system. The 'process' or 'procedure'. Teaching system design is a special design activity aimed at solving teaching problems and optimising learning, which has the general nature of the design discipline and follows the basic laws of teaching.'

1.2.3 Framework for instructional design

Tyler, an American educator, put forward the concept of "curriculum design", emphasizing that the primary task of instructional design is to determine the goals and plans for teaching. His four questions, "why teach (curriculum objectives), what to teach (curriculum content), how to teach (curriculum methodology), and how to evaluate students' learning outcomes (curriculum evaluation)", became the basic framework of instructional design[8]. Instructional design is nowadays based on the revised points of the 2022 version of the Compulsory Mathematics Curriculum Standards in Shining, the elements of teaching are arranged in an orderly manner, and the conception and planning of appropriate teaching programs are determined, including teaching content, teaching objectives, teaching key points, teaching difficulties, design of the board, main teaching methods, teaching tools, allocation of time for each stage, the process of teaching, teachers' activities, students' activities, the intention of the design of each stage, evaluation and reflection after class, etc. , post-course evaluation and reflection, etc.

1.2.4 Elements of instructional design

Instructional design can refer to the six elements of constructivism, i.e., context, collaboration, scaffolding, task, presentation, and reflection[9].

Element 1: Context. Setting up the teaching context is to make the mathematical content linked to the practical step is essential, the design of the teaching context can not only stimulate students' interest in learning, but more importantly, make the mathematical content closer to the actual life, more meaningful to learn, so that its content is no longer abstract, easy for students to accept.

Element 2:Synergy, that is, to play the strength of the team, brainstorming, cooperative learning, student-student collaborative learning and teacher-student collaboration are conducive to promote independent learning, inquiry learning, improve students' problem-solving ability and develop a sense of innovation.

Element 3: Scaffolding. According to constructivism, learning consists of two processes: eliciting existing knowledge from the mind and extracting new knowledge from the outside world, and eliciting original knowledge is the basis for new learning. Scaffolding refers to the bridge that connects the old knowledge with the new knowledge, and teachers should build this bridge in the teaching process so that students can construct new knowledge.

Element 4: Tasks. Learning tasks should be designed and assigned on the basis of students' learning bases and abilities, and appropriate tasks should be assigned for students to think about, preferably in their "zone of nearest development".

Element 5: Presentation. The results of student learning should be presented to the teacher and classmates, which facilitates learning assessment and develops students' self-reflective awareness and self-critical skills.

Element 6:Reflection. Self-reflection while learning facilitates self-assessment and teacher's assessment of students, and allows students to reflect and correct errors in learning in a timely manner.

1.2.5 Instructional design process

Based on the concept of deep learning, the instructional design process is set as follows: selecting teaching content, formulating teaching objectives, designing teaching process, and setting up teaching evaluation.

Selection of teaching content:According to the teaching progress, mathematics standard, students' receptive ability and learning basis to select appropriate teaching content, set the capacity of the curriculum. For the basic concepts of mathematics, mathematical definitions, properties, images, practical applications, etc. to make a reasonable choice to explain.

Formulate teaching objectives:According to the requirements of the curriculum standards, from the general objectives to the objectives of the school segments to the specific objectives of the course, based on the cultivation of students' core literacy, formulate the teaching objectives of the classroom. Teaching objectives should be in line with the students' learning situation, and should not deviate from the students' foundation, and should be based on the students' previous knowledge:Spiral up.

Designing the teaching process:The teaching process is the focus of the whole instructional design, and the design of the teaching process should pay attention to the interest, vividness and rationality, including the introduction of the teaching content, the interaction between teachers and students in the classroom, the cooperation and communication between students, and the summary of the classroom. The most important point in the teaching process is to make students understand the knowledge, rather than mechanically instilling knowledge.

Setting up Teaching Evaluation:Teaching evaluation is the evaluation of teachers' teaching and students' learning effects, including teachers' evaluation of students and students' self-evaluation.Teaching evaluation is set up to improve the teaching program and learning methods. Teaching evaluation should be done in a rational and comprehensive way. Teaching evaluation is conducive to improving teachers' and students' self-reflective skills and critical awareness.

1.3 Research on instructional design under deep learning theory

The Center for Curriculum and Textbook Development of Basic Education of the Ministry of Education (MOE) has successfully constructed a general framework for deep learning practice in the "Deep Learning" teaching improvement project (Figure 1-3-1). This framework divides the instructional design of deep learning into four core components, which are learning topics, learning objectives, learning activities, and continuous assessment[10]. These four components are organically unified in the instructional design of deep learning, with a particular focus on the alignment between objectives and content, activities and assessment. Under the guidance of core literacy, teachers set clear learning objectives, and then transformed the learning content into leading learning themes. At the same time, the teachers also designed a series of learning activities aimed at analyzing and solving real-life problems against the background of real-life situations, and actively encouraged students to participate in these learning activities on their own initiative.

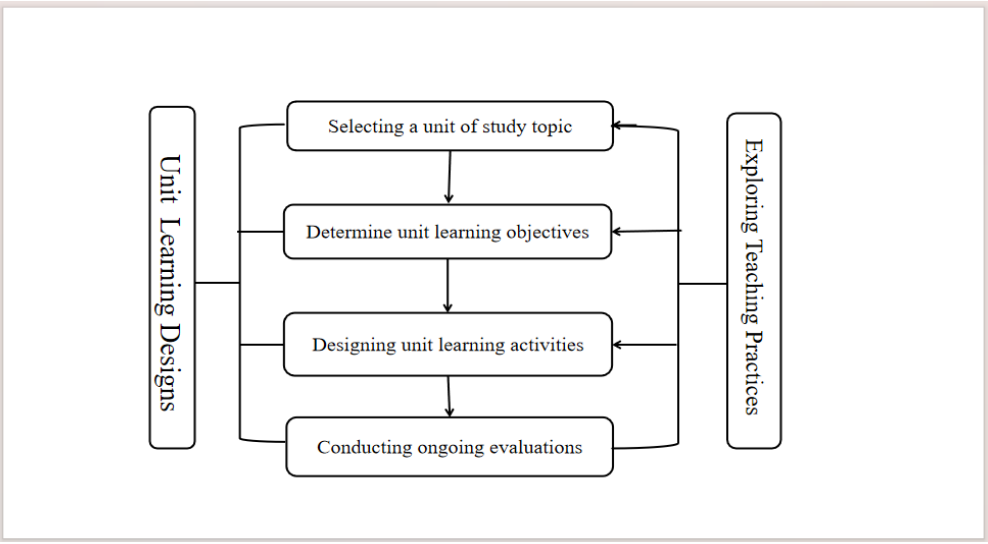


Figure 1-3-1 The Ministry of Education's Basic Education Curriculum and Textbook Development Center constructs a common framework for deep learning practices

Professor Ma Yunpeng also put forward the idea of instructional design for realizing deep learning (Figure 1-3-2). He believes that the instructional design for deep learning should be centered on three basic elements: subject content, student understanding, and subject teaching. Teachers of different disciplines need to creatively design teaching programs based on the characteristics of the discipline and their grasp of students' learning conditions. "The design and organization of teaching activities in a discipline are based on the analysis and understanding of discipline-specific content and students' learning status of that content[11]."

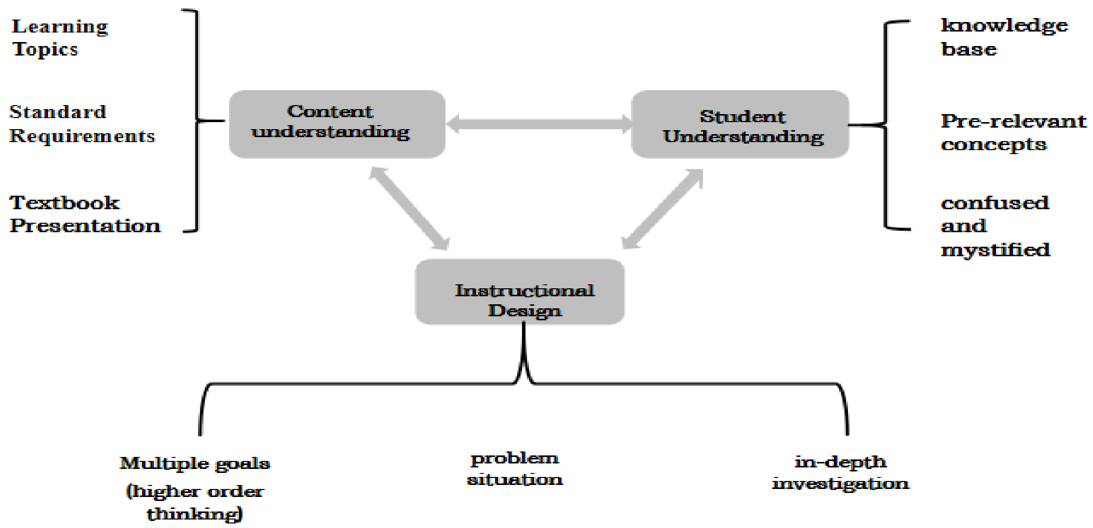


Figure 1-3-2 Instructional Design Ideas for Realizing Deep Learning Proposed by Professor Ma Yunpeng Selecting Unit Learning Topics

Li Chunmi, in his book Deep Learning: Toward Core Literacy (Subject Teaching Guide - Junior High School Physics), also puts forward the implementation strategies of deep learning in two major aspects: authentic problem solving and teacher's process guidance. Professor Hu Jiuhua proposed seven key strategies for implementing deep learning in junior secondary chemistry, including allowing students to experience the process of problem solving; teacher guidance on students' learning process skills; co-ordination of in-class activities and out-of-class tasks; designing assessment scales for core activity assessment, stage-by-stage progress assessment, and assessment of unit learning summaries; coping with accidents; effective use of information technology tools and professional development of teachers. Teacher professional development.

Zhong Qiquan believes that the instructional design of deep learning is essentially a constructivist instructional design, and that “subjectivity,” “dialogue,” and “synergy” are three complementary perspectives that are key to guaranteeing the quality of learning and improving teaching. The three complementary perspectives of “subjectivity”, “dialogicity” and “synergy” are the keys to guaranteeing the quality of learning and improving teaching. The instructional design for deep learning is not about what teachers teach, but about what students learn. It consists of six elements: context, collaboration, scaffolding, task, presentation and reflection. Instructional design for deep learning needs to focus on four laws, including problem selection, teacher role, learning objectives, and learning assessment [12].

Liu Jie believes that deep learning is an active and critical way of learning, which aims to cultivate and develop higher-order thinking skills. The study analyzes the value logic of deep learning from the aspects of learning content, learning objectives, learning mode, learning outcome and learning evaluation respectively, and therefore puts forward the basic principles of instructional design pointing to deep learning.The deep learning instructional design should implement the concept of student-centeredness, create an equal teaching and learning environment, set up the learning objectives pointing to deep learning, design situational and challenging learning tasks and construct the assessment that promotes students' development, and finally realize the deep integration of teaching and learning in classroom teaching[13].

## 2 A questionnaire survey on the current status of trigonometry function learning research for high school students pointing to deep learning

In order to realize deep learning, in addition to having an understanding of theories about deep learning, it is necessary to investigate the practice of deep learning, with the aim of having an in-depth understanding of the current situation of secondary school students' mathematical learning under the perspective of deep learning as well as the problems that exist. In this study, the questionnaire method, which is commonly used in educational science research methods, was used to develop a student questionnaire through the author's teaching practice experience during her educational internship and to analyze the problems that may exist in students' learning of trigonometry function based on relevant research.

2.1 Purpose of the questionnaire

Effective implementation of deep learning requires not only an understanding of the theory of deep learning, but also an understanding of the current situation of students' deep learning of trigonometry function. In addition, as the environment of the times improves and information technology changes more and more rapidly, and the reform of the new college entrance examination is also advancing, the only way to explore scientific and effective teaching strategies is to understand the current situation of students' attitudes and motivations in learning trigonometric functions, their learning methods and learning puzzles, and to analyze the problems and their causes after actual investigation and analysis.

2.2 Objects of the survey

The questionnaire survey took two classes of students in a high school in Tongren City, Guizhou Province, totaling 120 students, as the research subjects. The two classes have similar grades, with average grades in the middle of the grade. A total of 120 copies of the survey were distributed, and 113 copies were actually recovered, with a recovery rate of 94.2%, of which 108 were valid questionnaires, with an effective rate of 95.6%.

2.3 Design of questionnaire content

The author has developed this questionnaire by referring to the NSSE-China Deep Learning subscale, combining the characteristics of deep learning and the study of trigonometry function in high school. NSSE is the National Survey of Student Engagement in Learning (NSSE). NSSE-China is a modified version of the NSSE that was introduced into China by the Institute of Educational Research at Tsinghua University based on the learning situation of students in China. NSSE-China categorizes deep learning into the following dimensions. NSSE-China categorizes deep learning into the following three dimensions:

(1)Higher-order cognition, which asserts the higher-order thinking that students acquire while learning. (2)Integrative learning, which advocates that students need to integrate different types of knowledge and perspectives into their knowledge structure. (3) Reflective learning, which advocates that students regulate their own learning process and use their new knowledge to deepen their understanding[14].

Zhang Hao and Wu Xiujuan proposed six characteristics of deep learning in Exploring the Connotation and Cognitive Theoretical Foundations of Deep Learning, which are emphasizing critical understanding, emphasizing information integration, promoting knowledge construction, intentional transfer and application, problem-solving orientation, and encouraging active learning and lifelong learning. Referring to the characteristics of deep learning, Wen Haizhong identified the dimensions of the questionnaire as five dimensions: attitude and motivation, understanding and criticism, connection and construction, integration and reflection, and transfer and application[15], and this paper adopts these five dimensions to design the questionnaire, which is shown in Table 4-1, and the details of the questionnaire are shown in Appendix 1.

Table 4-1 Distribution of Questionnaire Content

| Survey dimensions | Purpose of the survey | title number |
|---|---|---|
| attitudes and motivation | Motivation to learn trigonometry function , propensity to acquire knowledge | 1.5.7 |
| understanding and criticism | The quality and spirit of being bold enough to refute, pursue, and ask rhetorical questions | 2.6.9 |
| connection and construction | Connecting old and new knowledge to build a knowledge network | 3.11.14 |
| integration and reflection | Integration of knowledge, self-evaluation and regulation of the learning process | 4.10.13 |
| transfer and application | Developing experience and applying knowledge to solve problems | 8.12.15 |

2.4 Quality check of questionnaire design

Examining the design quality of the questionnaire includes reliability analysis of the questionnaire design and validity analysis of the questionnaire design.

(1)Reliability analysis

The validity of questionnaire design refers to the validity of the questionnaire measurements and there are three common types of validity analysis, which are content validity, criterion validity and structural validity. This questionnaire was analyzed for structural validity using factor analysis.

The questionnaire was analyzed by the factor online analysis of spss21.0 software and the results are shown in Table 4-3, the KMO measure of the questionnaire design is 0.951>0.7, P=0.000. it can be concluded that the validity of this questionnaire is high.

Table 4-3 Calibration Statistics of The Questionnaire

| | | |
|---|---|---|
| | Kaiser-Meyer-Olkin | .951 |
| Bartlett's test of sphericity | rough chi-square (math.) | 944.202 |
| | Df | 105 |
| | Sig. | .000 |

2.5 Questionnaire results and analysis

The following is an analysis of the state of students' in-depth learning of trigonometry function in terms of five dimensions: attitude and motivation, understanding and critique, connection and construction, integration and reflection, and transfer and application:

(1)Attitudes and motivation

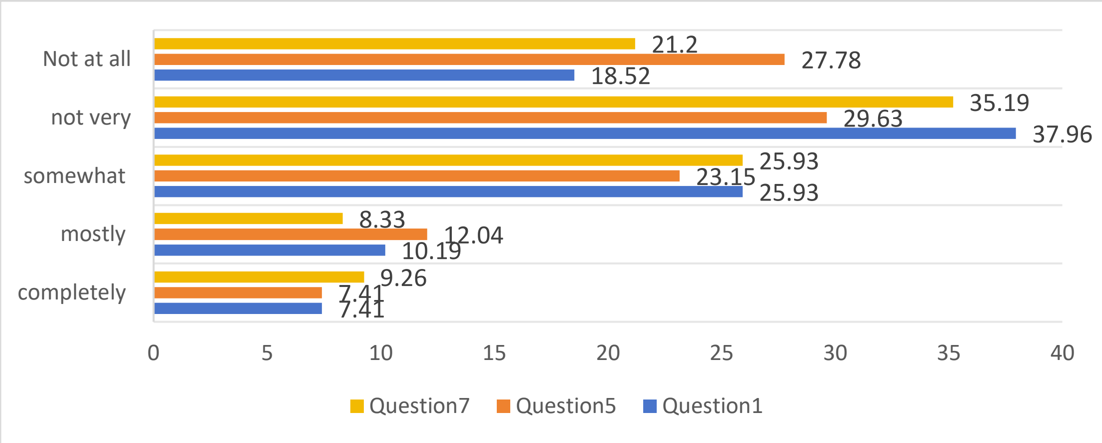


Figure 4-1 Attitude and Motivation Dimension Results Statistical Chart

In response to questions 1 and 7, together they reveal students' views on learning trigonometric functions. It can be clearly observed that as many as 37.9% of the students chose the option “not very”, which means that they have a more negative attitude towards learning trigonometric functions. Meanwhile, 25.93% of the students chose the option of “somewhat” in both Question 1 and Question 7, indicating that some of the students have some positive attitude towards learning trigonometry function, but on the whole, their attitude is not very positive. These data reflect that students may lack sufficient interest and enthusiasm in learning trigonometric functions, and some of them even do not have the good study habits of studying before class and reviewing after class.

Question 5 focused on students' motivation for learning trigonometry function. According to the statistical results, 23.15% of the students felt that their motivation for learning trigonometry function was “somewhat”, while 29.63% felt that it was “not very”. More significantly, 27.78% of the students directly chose “not at all”. These data show that most students do not study trigonometry function out of their inner love and interest, but may be driven by academic requirements or other external factors. This lack of internal motivation makes the learning process mechanical and passive, and it is difficult for students to get pleasure and sense of achievement from learning trigonometry function itself.

Comprehensive analysis of the above three issues, we can conclude that although some students hold a more positive attitude towards learning trigonometry function and have developed good learning habits, on the whole, most students lack internal motivation in learning trigonometry function, and the learning process is more passive and mechanical. This lack of interest and enthusiasm will not only affect students' learning results, but also be detrimental to their long-term development. Therefore, we need to further explore how to stimulate students' learning interest and internal motivation in order to promote them to learn trigonometric functions more positively and actively.

(2)Understanding and criticism

Question 2: In class, I will question and think about what the teacher is explaining.

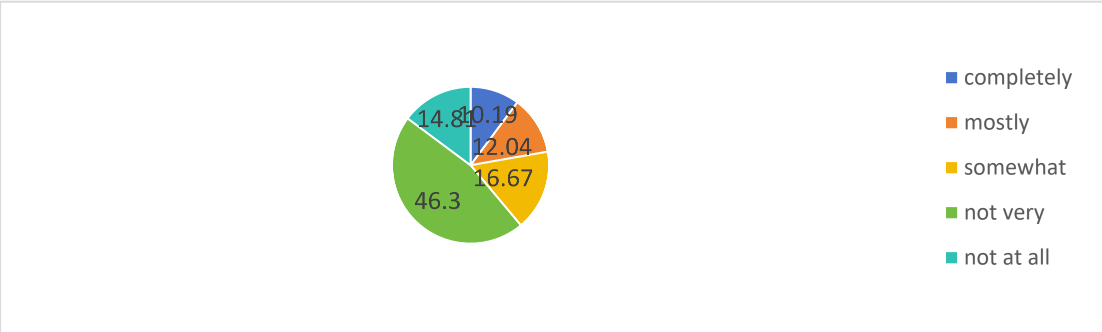


Figure 4-2 Statistical Chart of the Results of Question 2 of the Questionnaire Survey

As can be seen from the above figure, 46.3% of the students said “not very”, which means that nearly half of the students seldom questioned the content of the teacher's explanations. This phenomenon shows that in most cases, students hold a trusting or even convinced attitude towards the teacher's explanations in class, and seldom raise questions or express different opinions. This reflects that students generally tend to accept and agree with the teacher's viewpoints in the course of listening to lectures, rather than thinking deeply or questioning them.

Question 6: In class, when the class is discussing an issue, I carefully evaluate and reflect on the arguments and conclusions of others.

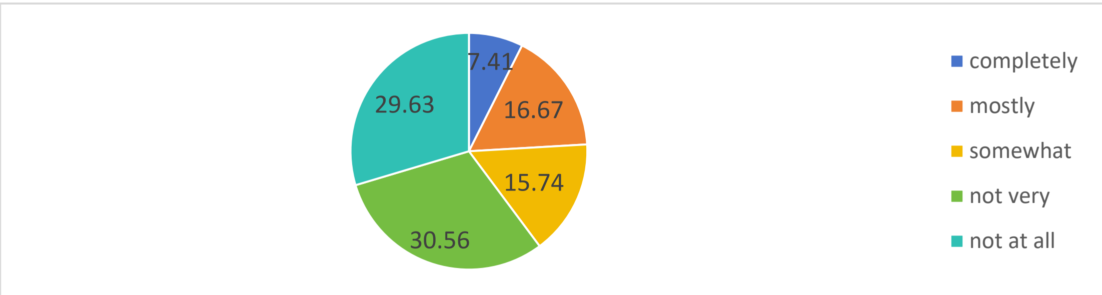


Figure 4-3 Statistical Chart of the Results of Question 6 of the Questionnaire Survey

We found that 30.56% of the students showed some hesitation and inadequacy in evaluating the arguments and conclusions of others, while 29.63% lacked the ability to make such evaluations at all. This data significantly reveals that most of the students have significant deficiencies in thinking deeply and evaluating the academic arguments of others.

Question 9: When newly learned trigonometric knowledge contradicts previous knowledge or common life knowledge, I will accept it for a while and look for answers to resolve the questions in my mind.

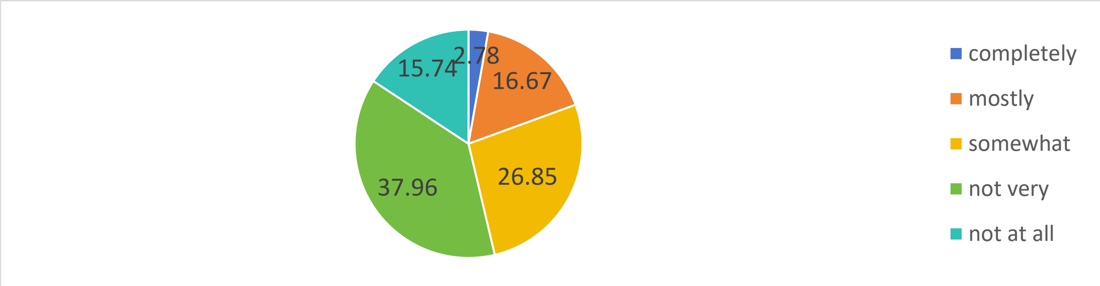


Figure 4-4 Statistical Chart of the Results of Question 9 of the Questionnaire Survey

From the data in the above chart, we can interpret the following information: 15.74% of the students were completely skeptical in accepting new knowledge, and did not show a positive mindset of seeking the truth; while 16.67% of the students chose “mostly ”, which means that they were skeptical in accepting the knowledge in the learning process; Further, 26.85% of the students indicated that they “somewhat”, meaning that they accepted the knowledge with doubts but did not explore it in depth to find solutions.

Summarizing these three observations, we can conclude that students appear to be relatively deficient in understanding and critical spirit. The majority of the students have an attitude of conviction about what is taught in the textbook and by the teacher, and they seldom think deeply about and evaluate the answers of others.

(3)Connections and constructions

Question 3: When studying trigonometric functions, I will take the initiative to connect to related knowledge I have previously learned, such as acute trigonometric functions in junior high school, and integrate it with knowledge from other subjects.

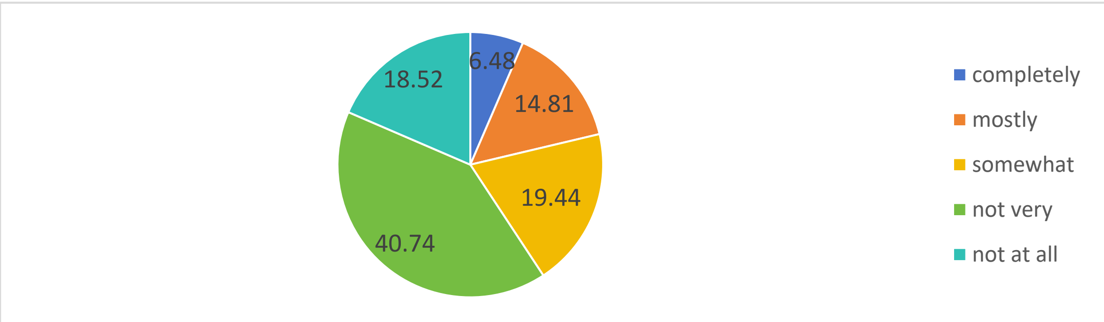


Figure 4-5 Statistical Chart of the Results of Question 7 of the Questionnaire

As shown in the figure above, we can see that when studying trigonometric functions, 19.44% of the students will occasionally relate to what they have learned before, which is due to the fact that they have learned to solve right triangles in junior high school, and they have some learning experience. 40.74% of the students are not very likely to relate to what they have learned before, which means that they will seldom relate to the old and the new knowledge in the process of learning.

Question 11: When solving trigonometry function problems, I am in the habit of solving more than one problem, thinking about more than one problem, and practicing several times to deepen my understanding.

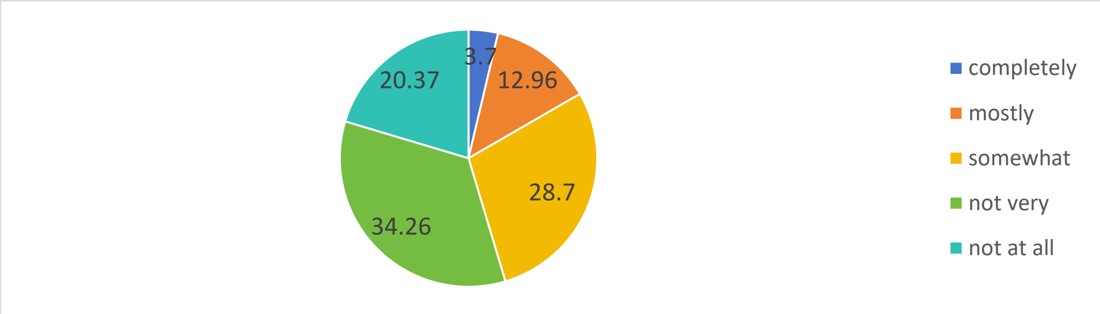


Figure 4-6 Statistical Chart of the Results of Question 8 of the Questionnaire

34.26% of the students chose the “not very” option, not very good at solving more than one problem, thinking more than one problem, doing more than one problem, lack of divergent thinking and associative ability. 28.7% of the students chose the “somewhat” option, occasionally solving more than one problem, thinking more than one problem and doing more than one problem, pursuing the speed of solving problems, neglecting to solve problems with multiple ideas and methods. They occasionally solve more than one problem, think more than one problem and do more than one problem, pursuing the speed of doing problems and neglecting the use of multiple ideas and methods to solve problems.

Question 14: I am good at using diagrams and charts to organize my knowledge of trigonometric functions so that I can understand the connections and differences between knowledge more clearly.

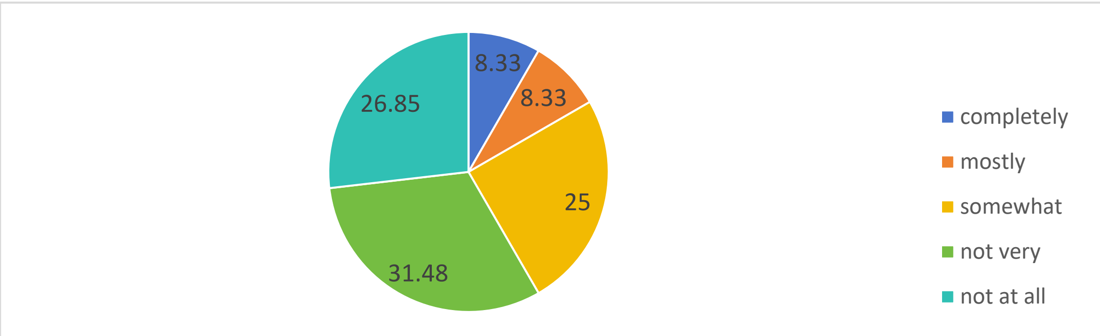


Figure 4-7 Statistical Chart of the Results of Question 9 of the Questionnaire Survey

25% of the students occasionally use graphs and tables to organize their trigonometric knowledge and build connections between knowledge, and 31.48% of the students are not very good at using graphs and tables to organize their trigonometric knowledge, which shows that most of the students do not take the initiative to look for connections between the contents of the various subsections of trigonometry function after class, and that the knowledge only exists in bits and pieces in their minds.

The results of these three surveys show that students do not do a good job in connecting new and old knowledge and building knowledge networks. Most students only focus on the knowledge in front of them and think that they can master the knowledge without connecting the new and old knowledge and building knowledge networks, plus the content of the chapter on trigonometry function is many and scattered, so the students have a hard time learning it.

(4) Integration and reflection

Question 4: In mathematics learning, I often reflect on my learning style and optimize it to adapt to different learning contents.

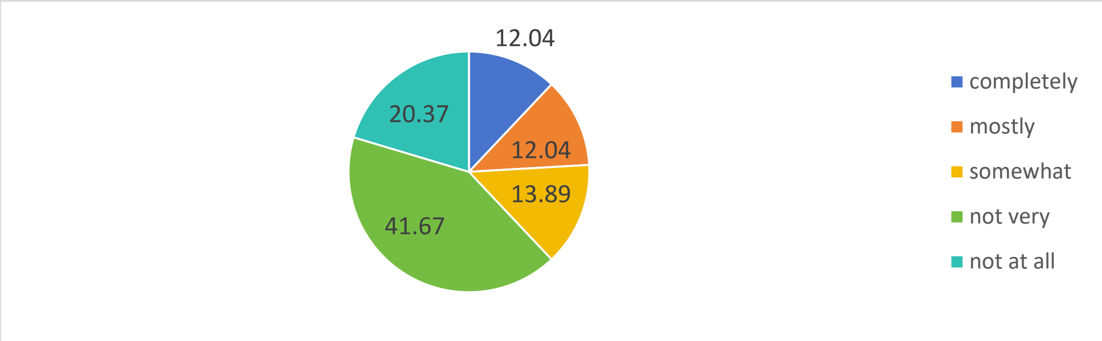


Figure 4-8 Statistical Chart of the Results of Question 4 of the Questionnaire

In this question, 13.89% of the students chose the option of “somewhat”, occasionally reflecting on and optimizing their learning styles, while 41.67% of the students were not very reflective and optimizing their learning styles. This shows that most students seldom reflect on their learning styles, and are more accustomed to studying in their own way, lacking the ability to reflect.

Question 10: I have a variety of learning methods and can apply them flexibly according to what I have learned and different scenarios to achieve the best learning effect.

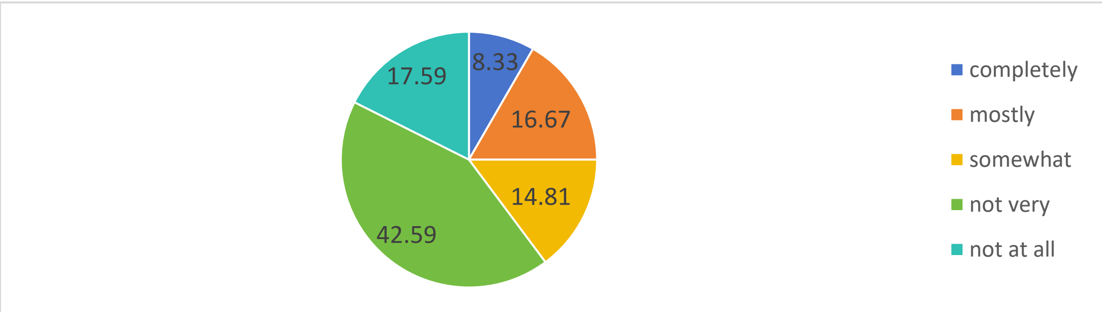


Figure 4-9 Statistical Chart of the Results of Question 10 of the Questionnaire Survey

14.81% of the students indicated that they could somewhat meet the requirement of “being able to apply what they have learned flexibly according to what they have learned and in different scenarios”, while the majority of the students did not have the flexibility to choose their learning methods according to the actual situation. 42.59% of the students chose the option of “not very”.

Question 13: I will organize, understand and memorize the trigonometric functions in the textbook in my own way to ensure that I can grasp them more firmly.

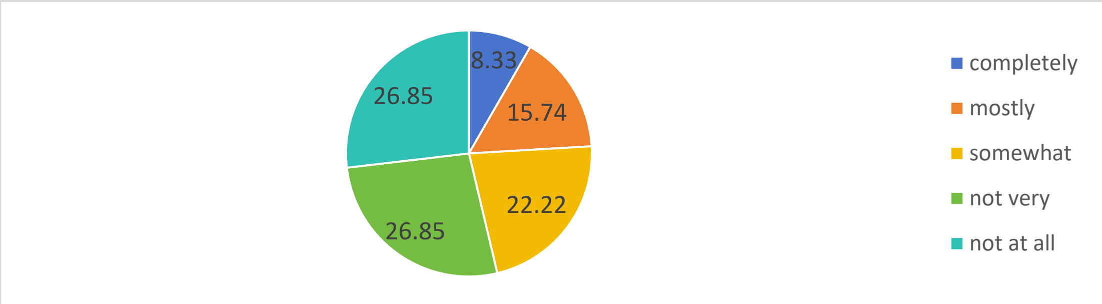


Figure 4-10 Statistical Chart of the Results of Question 13 of the Questionnaire Survey

According to the statistical results, we found that 26.85% of the students tend to memorize the content of the textbook directly and are less likely to organize it in their own way and memorize it after they have fully understood it. Such students usually do not take the initiative to connect and integrate their knowledge. On the other hand, 22.22% of the students indicated that they were "somewhat ", they occasionally tried to integrate the trigonometric knowledge in the textbook in their own way.

Combining the analysis of the above three questions, we can conclude that students are relatively weak in integrating their knowledge and reflecting on it. They seldom reflect deeply on their learning styles and take the initiative to improve their learning methods. Also, they are not very good at memorizing trigonometric knowledge by using effective memorization tools such as unit trees and tables.

(5) Transfer and application

Question 8: After completing a topic, I will try to change certain conditions to challenge myself in order to practice my problem solving skills.

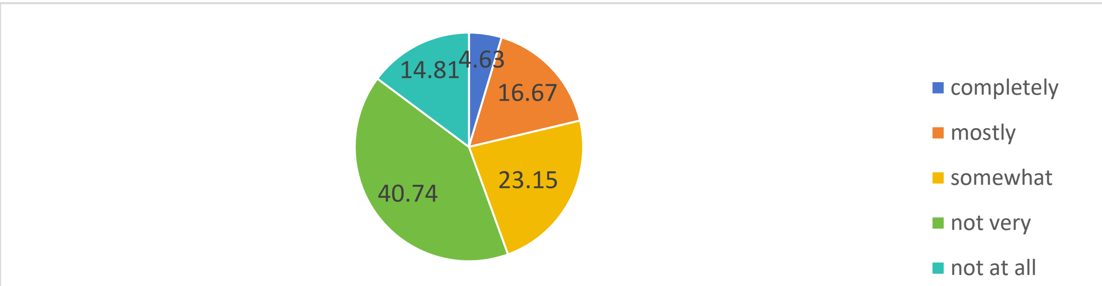


Figure 4-11 Statistical Chart of the Results of Question 8 of the Questionnaire Survey

As can be seen from the above graph, 40.74% of the students said that they are not very likely to change certain conditions to give themselves a challenge while working on a problem, and 14.81% of the students will not change the conditions at all to challenge the problem again . These data indicate that students have a task completion type of mentality when working on a problem and are not likely to change the conditions outside of the problem to give themselves a challenge.

Question 12: After practicing a few problems, I can summarize the general mathematical methods and ideas of the problem so that I can better deal with similar problems.

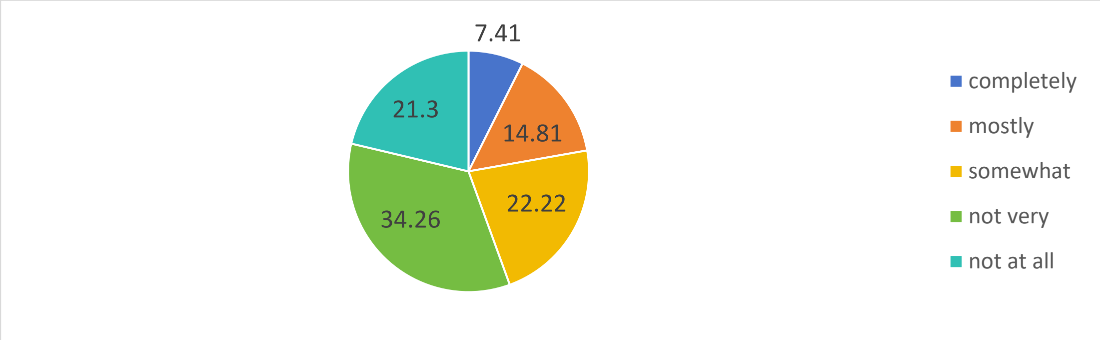


Figure 4-12 Statistical Chart of the Results of Question 12 of the Questionnaire Survey

In this question, 34.26% of the students were not quite able to summarize the mathematical ideas and literacy in them through a few questions without taking the initiative to do so, and 22.22% of the students were able to summarize the ideas and methods through a few questions occasionally. The main reason for this phenomenon is that students do not pay attention to mathematical literacy and methods of thinking, and they think they are not as practical as knowledge, unaware of their importance in mathematics learning.

Question 15: I can flexibly use my knowledge of trigonometry function to analyze and solve some problem situations in my life.

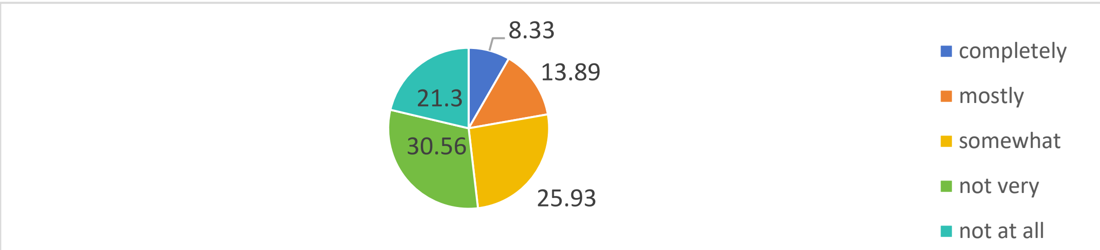


Figure 4-13 Statistical Chart of the Results of Question 15 of the Questionnaire Survey

25.93% of the students indicated that they were able to apply their knowledge of trigonometric functions occasionally to solve problems in specific problem situations. This shows that the introduction of the sine and cosine theorems had a positive impact on students' ability to apply them in real-life situations. The ability of this group of students to integrate this mathematical knowledge with life situations demonstrates the ability to apply the knowledge in practical situations.

Through the in-depth study of the three core problems, we observed a common phenomenon: after initially grasping the new knowledge, many students found it difficult to effectively transfer it to other related problems or contexts, and at the same time, it was difficult to extract the deeper mathematical thinking and literacy from it. This limitation hinders their development to a higher academic level to a certain extent.

Based on the in-depth analysis of the data from the 15-question questionnaire, we have come to the following conclusions: first, as far as learning attitudes and motivation are concerned, the students generally hold positive attitudes towards learning, and their study habits are also generally good. However, we also found that their internal drive was slightly insufficient, which might have affected their learning effectiveness and motivation for continuous learning to a certain extent. Second, at the level of knowledge comprehension and critical thinking, the students' performance reflected an over-reliance on the textbook and the knowledge imparted by the teacher. They generally lacked a critical spirit and were less likely to reflect and question deeply on what they had learned, or to analyze and evaluate the answers of others in detail. This phenomenon may limit their in-depth understanding and flexible application of knowledge. Furthermore, students have obvious deficiencies in integrating old and new knowledge as well as constructing knowledge networks. They tend to focus only on the knowledge points they are currently learning and neglect to effectively connect and integrate these knowledge points with their existing knowledge, thus making it difficult to form a complete knowledge system. In addition, we found that students' ability to integrate knowledge and reflect on it was relatively weak. They seldom make in-depth reflection and adjustments to their learning styles, which to a certain extent affects the optimization of their learning methods and the improvement of their learning efficiency. Finally, in terms of transfer consciousness and practical application ability, the students' ability to apply what they have learned to real-world problems still needs to be improved. It is often difficult for them to effectively transfer their newly learned trigonometric knowledge to other related problems or situations, and they lack the ability to learn by example, which limits their flexibility and creativity in problem solving to a certain extent. To summarize, students still have obvious deficiencies in knowledge comprehension, critical thinking, knowledge integration and transfer of application. In order to help students better master knowledge and improve their abilities, we need to further strengthen their critical thinking training, improve their knowledge integration ability, and guide them to better apply what they have learned to practical problems.

From this, we can get the following five main problems:

(1)Trigonometric content has many formulas and students lack enthusiasm for learning math.

(2)Students seldom understand deeply and lack critical thinking.

(3)Students focus on current knowledge and lack the ability to connect new and old knowledge.

(4)Students only focus on “learning” and lack a sense of reflective regulation.

(5)Students can solve one problem but lack the sense of transferring and applying.

## 3 Causes and countermeasures of problems in the instructional design of trigonometric functions based on deep learning theory

In this chapter, we analyze the causes of the five main problems that appeared in Chapter 2, and we propose countermeasures to solve the problems.

### 3.1 Analysis of the causes of problems in the design of trigonometry function instruction based on deep learning theory

Next, we analyze the five problems obtained from the above questionnaire specifically:

(1) Trigonometric functions contain many formulas, and students lack enthusiasm for learning mathematics.

In the view of many students, mathematics is a more abstract, boring and difficult to understand subject. The knowledge of trigonometric function chapter contains many formulas, and the motivation of most students to learn trigonometric function belongs to external motivation.

(2) Students seldom have in-depth understanding and lack critical thinking.

Students are seldom able to derive important trigonometric induction formulas rigorously without their own understanding.

(3) Students focus on current knowledge and lack the ability to connect old and new knowledge.

Most students do not take the initiative to connect old and new knowledge, process knowledge and build a knowledge network. The concept of trigonometric function is not a new concept for students, they have learned the concept of acute trigonometric function and solving triangles in junior high school, and they have a certain cognitive foundation. However, students' connection between old and new knowledge is still relatively superficial.

(4) Students only care about “learning” and lack the awareness of reflective regulation.

Students do not reflect on and optimize their learning methods, which is a kind of mechanical repetitive learning. Deep learning emphasizes self-evaluation and reflection, self-monitoring and regulation of learning. Students should pay attention to whether their learning methods are efficient and adjust their learning status in time after studying.

(5) Students can solve one problem but lack the sense of transferring and applying.

Most students, after learning one trigonometric knowledge, are difficult to digest and transfer it to other problems and situations, and to summarize mathematical ideas and methods to obtain higher levels of development.

3.2 Countermeasures of trigonometry function instructional design based on deep learning theory

In order to implement the requirements of the twentieth CPC National Congress on establishing moral character and further deepening curriculum reform in basic education, the Ministry of Education has revised the curriculum standards for a number of disciplines and condensed the core qualities of the disciplines. The core literacy of a subject is the concentrated expression of the value of human education, which is the correct values, necessary character and key abilities that students gradually develop through subject learning. Mathematics core literacy is the concentrated expression of the objectives of the mathematics curriculum, and it is the comprehensive expression of the thinking quality, key abilities, and emotions, attitudes and values with the basic characteristics of mathematics, which are gradually formed and developed in the process of mathematics learning and application. The core literacy of mathematics discipline includes: mathematical abstraction, logical reasoning, mathematical modeling, intuitive imagination, mathematical operations and data analysis[16]. In order to solve the problems and implement mathematics education based on core literacy, we embedded the core literacy of mathematics in the responses. The following are five countermeasures proposed to address the above five problems:

(1) Cultivate students' sense of application and stimulate learning interest

Cultivate students' sense of application in the teaching process, connect trigonometric functions with daily life, introduce some life examples, let students feel the application of trigonometric functions in real life, so as to enhance students' interest in learning. Enhance the use of geometric intuitive ability, the use of graphics to assist in understanding the concepts and properties of trigonometric functions, so that students can more intuitively understand the image of trigonometric functions and the law of change, reduce the learning difficulty. Adopt novel and interesting teaching methods, such as game-based teaching, interactive teaching, etc., to stimulate students' learning interest and initiative, so that students can learn trigonometric functions in a relaxed and happy atmosphere. Give students positive feedback and encouragement in a timely manner so that they can feel their progress and achievements, thus enhancing their learning motivation and self-confidence.

(2) Cultivate students' critical thinking and stimulate their desire for knowledge.

In order to cultivate students' critical thinking, teachers can try to adopt novel teaching methods, such as introducing life materials, carrying out mathematical games, organizing extracurricular activities in mathematics, etc., so as to arouse students' sense of curiosity and stimulate their desire for knowledge. So that students can take the initiative to try to discover and bravely explore meaningful mathematical problems in their daily learning, the sense of innovation helps to form the scientific attitude and rational spirit of independent thinking and daring to question.

(3) Cultivate students' mathematical abstract thinking and improve their knowledge integration ability

Teachers can ask guiding questions to help students connect new and old knowledge. Students can establish a knowledge framework in the learning process, classify and summarize new and old knowledge, be able to generalize general conclusions from specific problems, and form mathematical methods and strategies for better understanding and memorization.

(4) Cultivate students' sense of innovation and break the stereotyped thinking

Teachers should remind students to pay attention to their thinking and behavior all the time during class, and discover their problems and deficiencies in time. Examine and evaluate their thinking and behavior to find out the root causes of problems and solutions. Continuously learn and improve their knowledge and abilities to enhance their motivation for self-improvement and improvement. Try new ways of thinking and behaving, and break fixed thinking patterns and behavioral habits.

(5) Focus on knowledge transfer and expansion training

Teachers can guide students to connect and integrate the trigonometric knowledge they have learned with other mathematical knowledge to form a complete knowledge system by designing some comprehensive exercises and extension tasks. At the same time, teachers can also encourage students to apply their knowledge of trigonometric functions to other fields or practical problems, so as to improve their ability to transfer and expand their knowledge.

## 4 Conclusions and Remarks

In this paper, under the perspective of deep learning, combined with the characteristics of trigonometric function teaching, we conducted a student questionnaire survey on the current situation of deep learning of high school "trigonometric function", and concluded that there are certain problems in the deep learning of trigonometric function, which are mainly reflected in five aspects: Trigonometric functions have a lot of formulas, and students are not enthusiastic about learning mathematics; students seldom have a deep understanding of the lack of critical thinking; students focus on the current knowledge, lack of the ability to connect the old and new knowledge; students only care about "learning", lack of reflection and regulation of the consciousness; students will solve a problem, lack of transfer and application consciousness.

Based on the above five aspects, we put forward five countermeasures: cultivate students' sense of application and stimulate learning interest; cultivate students' critical thinking and stimulate curiosity; cultivate students' mathematical abstract thinking and improve their knowledge integration ability; cultivate students' sense of innovation and break their thinking stereotypes; and pay attention to the transfer of knowledge and extension training. Point out how to design the teaching of trigonometric function knowledge module under the guidance of deep learning theory.

There are many shortcomings in this paper, such as the small sample size in the questionnaire survey process, which is limited to two classes; and the time for the practical research is a little bit rushed. The teaching countermeasures proposed in this paper still need to be adjusted and improved by teachers according to the actual teaching situation. At present, many scholars are continuing their research on deep learning, and we believe that with the efforts of many experts and scholars, the research on deep learning theory and high school trigonometry function teaching will go further.

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**Appendix 1**

A survey on the current status of trigonometry function learning of high school students under the deep learning theory

Hello! Thank you very much for taking part in this research, this questionnaire is designed to find out how people learn. The questionnaire is anonymous, there are no right or wrong answers to the questions, and the results of the answers are only used as a reference basis for this research. Therefore, please truthfully choose the option that best meets your actual situation, and thank you for your cooperation!

1. I became interested in trigonometry function class. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

2. In class, I usually accept the teacher's explanations of points, but I also keep my own questions and thoughts. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

3.When studying trigonometric functions, I will take the initiative to connect with related knowledge I have learned before, such as acute trigonometric functions in junior high school, and integrate them with knowledge from other subjects. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

4.In mathematics, I reflect on my learning style from time to time and optimize it to adapt to different learning contents. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

5. I learn trigonometry function with a lot of initiative and enjoy it. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

6. In class, when the class is discussing an issue, I carefully evaluate and think about the arguments and conclusions of others. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

7. I have developed a good habit of studying trigonometry function before class and reviewing it after class. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

8. When solving trigonometry function problems, I am used to solving more than one problem, thinking more than one problem, and practicing several times to deepen my understanding. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

9.When newly learned trigonometric knowledge contradicts previous knowledge or common sense in life, I will temporarily accept it and look for answers to resolve the questions in my mind. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

10. I have a variety of learning methods and can apply them flexibly according to what I have learned and different scenarios to achieve the best learning results. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

11. When solving trigonometry function problems, I am used to solving more than one problem, thinking more than one problem, and practicing several times to deepen my

understanding. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

12. After completing a topic, I will try to change certain conditions to challenge myself to work on my problem solving skills. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

13. When solving trigonometry function problems, I am used to solving more than one problem, thinking more than one problem, and practicing several times to deepen my understanding. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

14. I will organize, understand and memorize the trigonometric functions in the textbook in my own way to ensure a stronger grasp. ( )

A. completely B. mostly C. somewhat D. not very E. not at all

15. I can flexibly use my knowledge of trigonometric functions to analyze and solve some problem situations in my life. ( )

A. completely B. mostly C. somewhat D. not very E. not at all