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A Practical Study on Cultivating High School Students' Scientific Thinking Using the KWL Model—A Case Study of "The Discovery of Growth Hormone"

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Abstract

The General Biology Course Standards for Senior High School (2017 Edition Revised in 2020) require the cultivation of students' core biological literacy from four aspects: life concepts, scientific thinking, scientific inquiry, and social responsibility. Scientific thinking literacy helps students use biological facts and evidence to explore and explain life phenomena and laws, and examine or demonstrate biological and social issues. The KWL (know want learned) model, with the help of KWL forms, is conducive to students' active construction of knowledge and development of thinking ability, which is a new attempt to cultivate students' scientific thinking. In order to investigate the effectiveness of KWL mode in cultivating high school students' scientific thinking, based on mastering the current situation of biology teachers and students' scientific thinking in practice schools through interviews and questionnaires, this paper selected the high school biology "auxin discovery" for the teaching practice of KWL mode, and analyzed the role of the application of this mode in the process of cultivating students' scientific thinking through educational experimental research method. The main results are as follows: (1) the application of KWL mode in high school biology teaching is conducive to cultivating students' scientific thinking. (2) KWL mode is conducive to the development of students' induction and generalization, model and modeling, and critical thinking. (3) KWL teaching mode can help student's better study biology.

Keywords: KWL mode; Scientific thinking; High school biology teaching.

1. Introduction

Scientific thinking is an important dimension of the core literacy of biology. Cultivating scientific thinking not only reflects the requirements of the new curriculum reform, but also can cultivate students' core literacy of biology, which is conducive to the comprehensive development of students. The KWL teaching model, the K-W-L model, the KWL strategy, and the "knowledge thinking learning" model. Although there are different names in some studies, the above names refer to the know want learned model, which is abbreviated as the KWL model. It refers to a teaching model proposed by ogle, an American scholar, in 1986 (OGLE, 1986), through which students learn unknown knowledge on the basis of known experience. K means "what do I know"? W means "what do I want to learn". What do I want to know? L means "what have I learned"?

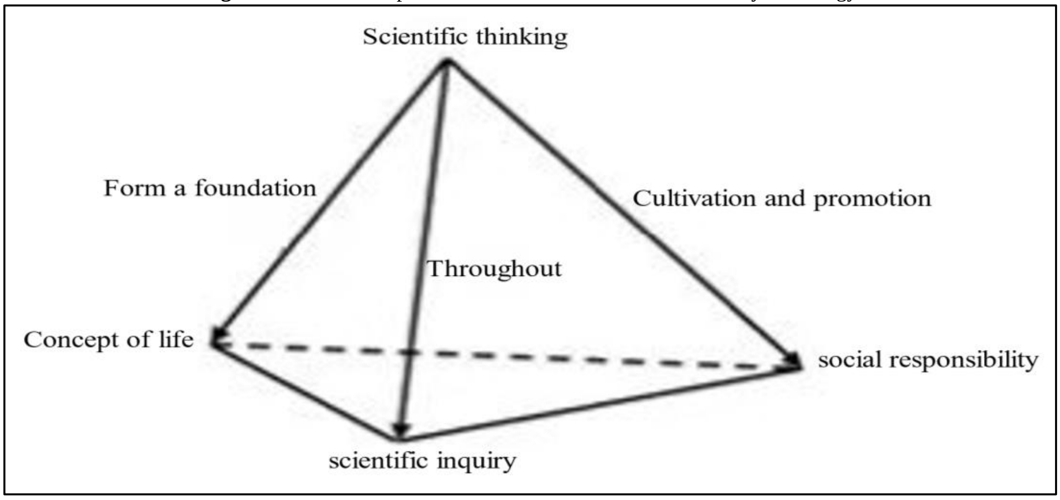
1.1. Cultivating Scientific Thinking is the Requirement of the Development of the Times and the New Curriculum Reform

In 2014, China issued the opinions on comprehensively deepening curriculum reform and implementing the fundamental task of Building Morality and cultivating people, which requires the development of students' core literacy and the promotion of students' all-round development. After that, in order to develop students' core literacy as the goal, establishing the core literacy system of various disciplines has become the focus of the new round of high school curriculum reform in China. The new curriculum standard, which closely follows the new requirements of the new era and cultivates students' core literacy, is born (Yunyun, 2020).

1.2. Scientific Thinking is an Important Part of the Core Quality of Biology

The core literacy of biology includes the concept of life, scientific thinking, scientific inquiry and social responsibility, which form a whole and jointly reflect the educational value of biology. As a key part of the "ability" factor in the core quality system of biology, scientific thinking is indispensable for the establishment of the concept of life, the practice of scientific inquiry, and the cultivation of social responsibility (Yongping, 2018).

Figure-1.1. relationship between four dimensions of core literacy in Biology



1.3. KWL Mode is an Active Exploration of Cultivating High School Students' Scientific Thinking

The KWL model (know want learned model), which links students' known and unknown new and old knowledge and helps students to participate in the process of knowledge construction, has attracted strong attention from educational and teaching researchers since its establishment (Yan *et al.*, 2020). The study found that KWL mode can stimulate students' interest in learning and improve students' learning efficiency (Szabo, 2007). At the same time, KWL form, as a tool for thinking visualization, is conducive to students' autonomous learning and development of critical thinking ability (Raines, 2018).

2. Research Status

2.1. Cultivation Status of Scientific Thinking

Thinking is one of the most important high-level psychological activities of human beings. The existence of thinking makes human beings and animals significantly different. People attach great importance to thinking, and the research on thinking has never stopped. Confucius in the spring and Autumn Period in China realized the importance of thinking, and he proposed that "learning without thinking is useless". Socrates in ancient Greece proposed "midwifery" to cultivate learners' critical thinking. It can be seen that the ancients had different understanding and Research on the cultivation of thinking very early. With the development of the times, people's understanding of thinking is more and more profound. Many experts and scholars at home and abroad have conducted in-depth research on the cultivation of thinking.

Combing the modern research literature, we can find that the research on the cultivation of scientific thinking mainly focuses on the cultivation theory of various thinking methods, the measurement and evaluation of thinking, and the cultivation of scientific thinking in subject teaching. For example, Weiping Hu and others have built a three-dimensional structure model of teenagers' scientific thinking ability after years of research, and put forward effective suggestions for the cultivation of thinking ability (Weiping and Chongde, 2003), which provides an important reference for subsequent research on scientific thinking. Yanto et al. Divided the scientific rational ability into three aspects: analysis, evaluation and creation, and formulated the evaluation framework and description index (Subali *et al.*, 2019). The research of these scholars at home and abroad provides guidance and basis for the research of thinking on the theoretical level. Qian Cai et al. Studied and discussed the ideas and methods of cultivating scientific thinking in physics teaching activities in real situations (Qian *et al.*, 2021). On the basis of clarifying the connotation of chemical scientific thinking, Xinyang Hu and Hualin Bi put forward the psychological mechanism and training path of chemical scientific thinking (Xinyang and Hualin, 2022). These teaching researches on the cultivation of thinking in the teaching of different disciplines have greatly broadened and enriched the theoretical and practical research of scientific thinking.

For scientific thinking, Kuhn believes that it is a process of conscious exploration of knowledge (Kuhn, 2005). Chongde Lin and Weiping Hu have studied the scientific thinking ability of teenagers. They believe that scientific thinking is the "indirect, generalized and dynamic reflection" of human brain on things and the relationship between things (Weiping and Chongde, 2003). It can be seen that different scholars have different cognition of scientific thinking.

This study adopts the interpretation of scientific thinking in the new curriculum standard: respect for facts and evidence, advocate rigorous and pragmatic attitude towards knowledge, and use scientific thinking methods to understand things and solve practical problems (Ministry of Education of the People's Republic of China, 2017). The explanation divides scientific thinking into three key points: scientific thinking attitude, scientific thinking habits and scientific thinking ability, and achieves the unity of scientific thinking in three levels of values, character and ability. Of course, the improvement of scientific thinking ability, the cultivation of attitude and the formation of habits are inseparable from scientific thinking methods.

There are various ways of thinking, such as analysis, synthesis, abstraction, generalization, etc. The thinking methods in different disciplines have both common parts and different parts reflecting the characteristics of their respective disciplines. There are different ways of thinking in different disciplines. In biology, the new curriculum standard clearly mentions five scientific thinking methods, mainly induction and generalization, deduction and reasoning, model and modeling, critical thinking and creative thinking.

2.2. Development and Research Status of KWL Mode

The KWL model was first proposed by Donna ogle, an American scholar, in 1986. As shown in table 2.1, this mode uses visual charts to ask questions, and integrates students' known, wanted to know and learned knowledge through three modules: "what I know", "what I want to know" and "what I have learned" (OGLE, 1986). Studies have found that this model can effectively activate learners' relevant knowledge and experience (Sampson, 2002), help students sort out the connection between new and old knowledge, and thus improve the knowledge system framework.

Table-2.1. Example of KWL table

（K） What Do I Know	（W） What Do I Want To Know	（L） What Have I Learned
I know……	I want to know……	I learned……

With the application of KWL mode, foreign researchers have adapted KWL mode in actual teaching practice, developed and refined a new model based on the original one, such as applying kwl+(know want learned plus) teaching mode to improve students' comprehensive learning ability in reading teaching (Amelia and Kamalasari, 2018), and applying THC (think how include) teaching mode to help students think better (Cannon and Crowther, 2004).

Combing the literature, it is found that whether the application of KWL mode to cultivate students' scientific thinking is applicable to all types of schools and students at all levels is not verified without sufficient data support. Therefore, my research practice in Xinyang senior high school explores the effectiveness of KWL mode in cultivating high school students' scientific thinking according to the problems existing in the current research.

3 Research Purpose and Significance

3.1. Research Objective

Through the analysis of the research background and research status, this study will investigate the effectiveness of KWL mode in cultivating high school students' scientific thinking, and provide effective teaching reference. This study uses the educational experiment method to carry out the biology teaching practice of KWL mode, and analyzes the influence of the application of this mode on students' scientific thinking and academic performance through questionnaires, interviews and other methods, in order to obtain a new teaching mode of cultivating scientific thinking, and provide an important reference for the future education and teaching research.

3.2. Research Meaning

Combining the KWL mode based on constructivist learning theory with the cultivation of scientific thinking in biology teaching, and using KWL form to build "learning knowledge" on the basis of students' "known" and "want to know", students' learning initiative can be brought into play, and the improvement of students' thinking can be promoted in the process of solving problems and constructing knowledge. This study can not only enrich the theoretical research of scientific thinking training strategy, but also broaden the application path of KWL in biology teaching. In addition, effective suggestions are put forward for the teaching practice in the internship high school, which will provide reference for future teaching research.

This study is conducive to the implementation of the requirements of the new curriculum reform. KWL mode is a new teaching mode to broaden and cultivate students' scientific thinking. The practice of this mode in biology teaching is conducive to the implementation of the "student-centered" education concept, pay more attention to the development of students, and give play to the educational function of the discipline. This study is conducive to promoting the cultivation of students' thinking ability. KWL mode emphasizes that students are the main body of learning activities, stimulates the curiosity and thirst for knowledge of biology, and allows students to ask questions and try to find answers based on their existing knowledge and experience.

This study is conducive to the professional development of biology teachers. In the application process of KWL mode, teachers need to have stronger control over the classroom and make continuous progress in education and teaching knowledge and ability, so as to promote the professional development of teachers and realize the mutual benefit of teaching and learning.

4. Research Method

4.1. Literature Research Method

Through the method of literature research, the collection, collation and analysis of literature can have a more scientific and comprehensive understanding of the content of the study, find arguments, find new ideas and generate new methods from previous studies (Du, 2013). On the basis of deeply understanding the biological education concept in the new curriculum standard, after selecting the literature suitable for this research topic, this paper summarizes the research and development of scientific thinking training and KWL mode, and analyzes the advantages and disadvantages of the current research, so as to find the entry point of this research and provide theoretical support for this teaching practice research.

4.2. Questionnaire Survey Method

In the early stage of the study, we investigated the scientific thinking of the students in grade two of senior high school in the internship school. In the early and late stages of teaching practice, the questionnaire was used to investigate the students in the experimental class and the control class to obtain the relevant data of the pre-test and posttest, so as to analyze the results of teaching practice.

4.3. Interview Method

Through in-depth and extensive conversations and discussions with teachers, understand their cognitive level and teaching situation of scientific thinking, and understand the real situation and dilemma of front-line biology teachers.

4.4. Educational Experimental Research Method

To investigate the influence of KWL mode on high school students' scientific thinking, this study will select the experimental class and the control class, and apply KWL mode to teaching practice in the experimental class. This paper analyzes the application of KWL mode in biology teaching by comparing the scientific thinking of the experimental class before and after and comparing the scientific thinking of the experimental group and the control group.

4.5. Mathematical Statistics

In this study, Excel software and IBM SPSS statistics 26 (hereinafter referred to as SPSS) software were used to statistically analyze the data through descriptive analysis, difference analysis, correlation analysis and other methods.

5. The Teaching Practice Design of KWL Mode in High School Biology

5.1. Practice Plan

In order to better understand the application effect of KWL mode in biology classroom teaching, the educational experiment method was used for research. The specific process is as follows: select the experimental object -- determine the pre-test level of the research object -- design the teaching design of KWL mode and carry out the Teaching -- carry out the post test on the research object -- analyze the pre-test and post test results -- get the conclusion.

5.1.1. Research Object

According to the single variable principle and the control principle of the experiment, two classes with no significant difference in scientific thinking and biological performance should be selected as the control class and the experimental class to carry out the biology teaching practice of KWL mode.

The scientific thinking of four classes randomly selected from grade two of senior high school is statistically analyzed, as shown in Table 5.1. According to the following one-way ANOVA results, the significance test results of scientific thinking as a whole and all dimensions are greater than 0.05, and there is no difference in the class.

Table-5.1. description of the analysis results of the differences of each dimension of scientific thinking in the class

variable	Class	Students	average value	standard deviation	F	Sig.
Induction and generalization	Class 7	66	3.58	0.77	1.211	0.306
	Class 8	67	3.69	0.75		
	Class 9	67	3.76	0.63		
	Class 10	67	3.80	0.72		
Deduction and Reasoning	Class 7	66	3.71	0.63	0.976	0.404
	Class 8	67	3.80	0.65		
	Class 9	67	3.83	0.58		
	Class 10	67	3.66	0.69		
Model and modeling	Class 7	66	3.30	0.88	0.195	0.900
	Class 8	67	3.36	0.80		
	Class 9	67	3.41	0.82		
	Class 10	67	3.37	0.84		
critical thinking	Class7	66	2.75	0.64	0.217	0.884
	Class 8	67	2.82	0.68		
	Class 9	67	2.73	0.66		
	Class 10	67	2.76	0.71		
Creative Thinking	Class 7	66	2.61	0.74	0.146	0.932
	Class 8	67	2.58	0.75		
	Class 9	67	2.64	0.75		
	Class 10	67	2.65	0.69		
Scientific thinking	Class 7	66	3.19	0.63	0.214	0.887
	Class 8	67	3.25	0.65		
	Class 9	67	3.27	0.61		
	Class 10	67	3.25	0.66		

Table-5.2. average biological scores of classes 7, 8, 9 and 10 in Senior 2

class	Students	Average score / points
Class 7	66	67.3
Class 8	67	68.8
Class 9	67	69.0
Class 10	67	69.0

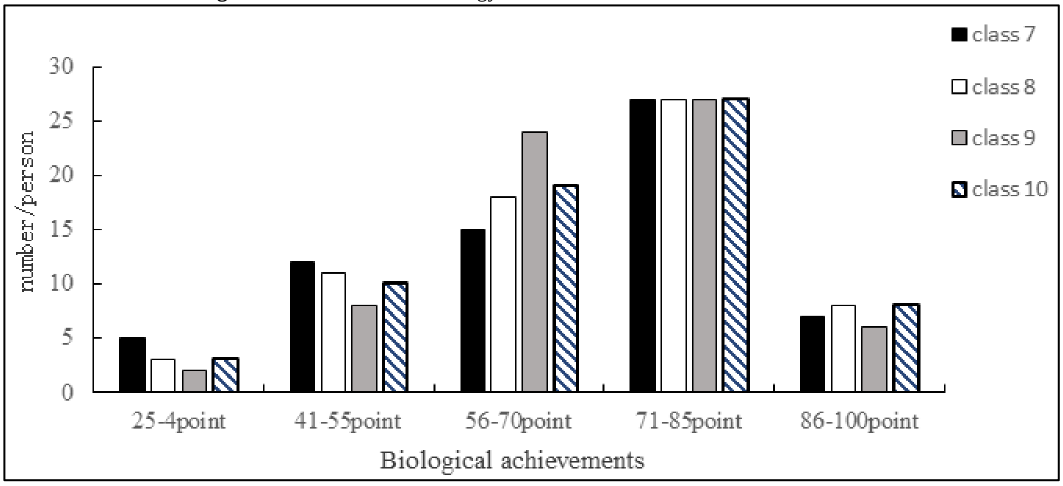
Table 5.2 shows the average biological scores of the four classes. It can be seen that the average biological scores of the four classes are close and slightly different. In order to further understand whether the biological scores of each class are significantly different, the results of one-way ANOVA are shown in table 5.3, and p=0.902 is greater than 0.05, indicating that there is no significant difference in the biological scores of the four classes.

Table-5.3. statistics of differences in Biology scores among classes

variable	Class	Number/person	Average	standard deviation	F	Sig.
Biological achievements	Class 7	66	67.3	16.80	0.192	0.902
	Class 8	67	68.8	15.66		
	Class 9	67	69.0	13.83		
	Class 10	67	69.0	15.46		

Figure 5.1 shows the distribution of the number of students in the four classes in different biology grades. In these four classes, the number of students in class 7 and class 9 in the score range of 25-40 and 56-70 is slightly different from other classes. However, the number of students in class 8 and class 10 in the biological score range of 25-40, 41-55, 56-70, 71-85 and 86-100 is relatively close.

Figure-5.1. distribution of Biology scores in classes 7, 8, 9 and 10 of Senior 2



Based on the above results, the four classes are similar in biological performance and scientific thinking, and there is no significant difference. Finally, class 8 and class 10, whose performance levels are more similar, are selected as the research objects of this teaching practice. Eight classes were randomly selected as the experimental class for KWL mode biology teaching; Class 10 was selected as the control class for the conventional mode of biology teaching.

5.1.2. Experimental Arrangement

According to the students' scientific thinking and academic level, two parallel classes were selected as the experimental class and the control class. The independent variable of this experimental study was determined as KWL teaching mode. The experimental class was taught with KWL mode, while the control class was a conventional teaching mode. The dependent variable is the development of students' scientific thinking. It is assumed that different teaching modes will have different effects on the development of students' scientific thinking. The independent variables are teachers' teaching attitude, class arrangement, teaching progress and so on. In the teaching of the two classes, in addition to the different teaching modes, we should try our best to keep the consistency of unrelated variables, so as not to affect the experimental results, making the experiment more rigorous and the results more reliable.

The normal progress of biology teaching was carried out in the experimental class for one semester, and the normal mode was used in the control class to maintain the consistency of relevant unrelated variables. After a semester of teaching, the students in the experimental class and the control class were tested with the scientific thinking test questionnaire. Compare the changes of scientific thinking of the experimental class before and after the application of KWL mode, and compare with the students' scientific thinking of the control class, and analyze the influence and role of the application of KWL mode on different aspects of students' scientific thinking.

After that, according to the results of biology teaching practice and classroom observation of KWL mode, this paper summarizes the effect of KWL mode applied to high school biology teaching on students' scientific thinking.

5.2. Implementation of KWL Mode

5.2.1. Preparation before Class

To apply KWL mode in high school biology classroom teaching and fully integrate this mode with biology teaching content, teachers need to make preparations before class so that KWL mode can be effectively carried out.

(1) Making students' KWL learning form

According to the three links of "knowing", "wanting to know" and "learning to know" of KWL mode, students' KWL learning form is made as shown in table 5.4.

Before the implementation of KWL mode teaching, teachers prepare and distribute KWL forms to students to briefly guide students on how to fill out the learning forms. In the later stage of teaching practice, students usually draw a simple KWL form to develop good learning habits and thinking habits.

Table-5.4. student KWL learning form

K(Known)	W(Wanted to know)	L(Learned)
What have I learned from my previous study and life experience?	What do I want to know about this class?	What have I learned from this lesson?

(2) The teaching design of teachers' KWL mode.

Students should complete the three links of "knowing", "wanting to know" and "learning to know" in the classroom, so when designing the teaching plan of KWL mode, teachers should preset the completion of each link of students, so as to better guide students' learning and thinking.

For the "known" of students, teachers should understand the students' learning situation before class, including the knowledge base, mode of thinking, interest and other aspects of students in this class. When students are difficult to contact the previous knowledge, they can supplement it and strengthen the logical framework of students' knowledge. For students' "want to know", teachers should analyze what students want to know in advance? In addition, teachers should preset questions according to the teaching objectives of this class and guide students during discussion. For students' learning knowledge, teachers should preset students' summary learning situation, and guide students' attention and review of key knowledge.

5.2.2. KWL Mode Implementation Steps

(1) K link

In link K, students should fill in "what do I know". Teachers first provide relatively simple materials related to the content of this lesson, such as the history of science or biological models, so that students can understand the learning theme or key concepts. Students fill in "column K" through group cooperation, recalling and discussing the knowledge they have learned and connecting with life experience according to the theme. Teachers can also confirm and appropriately supplement the content of students' answers to encourage students to think.

(2) W link

In the w link, students should fill in "what do I want to know". The teacher guides the students to discuss and ask questions related to the content of this class.

(3) L link

After learning the new lesson, students communicate and summarize the learning content in the L link, and record it in the "l column" of the form. Groups discuss with each other, check whether their questions are answered according to column W, and check whether their previous knowledge is correct according to column K.

After the KWL mode classroom teaching, students completed the KWL learning form and completed the knowledge construction of this class. The three steps of knowing, wanting to know and learning to know help students complete the construction of knowledge concept from their own original knowledge experience and life experience, and promote the improvement of students' thinking. Students promote the improvement and development of scientific thinking literacy in the summary of biological concepts, laws and other knowledge frameworks, in the complex thinking of different links of inquiry activities, and in the dialectical treatment and analysis of biological problems in social affairs. Teachers know students' knowledge base and learning interests according to students' KWL form, and also monitor students' learning situation with the help of the form, which is conducive to teachers' better teaching and evaluation, and better cultivate students' core quality of biology.

5.3 Application Case of KWL Teaching Mode -- Discovery of Plant Auxin

(1) Textbook analysis

The discovery of auxin is the first section of chapter three. Ask the question from the phenomenon of living: why do plants bend to light?, Stimulate students' "want to know" and lead to the exploration of the history of biological sciences such as the discovery of auxin in this section. The discovery of auxin in this section is the basis for learning plant hormones and their physiological functions, which is very important for later learning.

(2) Analysis of learning situation

Before learning this section, students can contact some phenomena in life and have a certain understanding of plant tropism. Through learning this section, students can further understand the above phenomena. Although the concept of auxin is relatively abstract, students' learning ability and thinking level have developed to a higher stage. The study on the regulation of animal life activities in the previous two chapters can also reduce the difficulty of this section.

(3) Teaching objectives

Describe the production location, transportation mode and distribution characteristics of auxin, and form the concept of life such as structure and function. Through the experimental inquiry learning of auxin discovery process, construct scientific concepts, and experience the creative thinking and rigorous scientific methods of scientists. Through scientific thinking methods such as induction and deduction, the research hypotheses and experimental design ideas of Darwin, Jason, Bayer, winter, etc. are expressed in the form of schema, and the discovery process of auxin is explained.

(4) Key and difficult points in Teaching

Teaching focus: The discovery process of auxin;

Teaching difficulties: The discovery process of auxin ; Rigorous analysis of scientific experiment design.

(5) Teaching process

KWL teaching mode of the discovery of plant auxin			
Teaching process	**Teacher activities**	**Student activities**	**Design Intention**
Lead-in	Display picture: plants growing out of the window, causing students to think: what	Students realize the phototropism of	The k-link and l-link of KWL mode start

	is this phenomenon? Do you know any similar phenomenon in life? According to the students' answers, the teacher introduces the concepts of phototropism and isotropic movement, and guides the students to discuss: "what do I want to know?".	plants, and think about "what do I know" and fill in column K, then report to the group. Students discuss and fill in column L.	with the familiar phenomena in students' life, so that students can have a deeper understanding of the definition of plant phototropism, and stimulate students' interest in exploration.
The discovery process of auxin	Ask the question: what is the reason of plant phototropism? This leads scientists to explore the causes of phototropism. Show the schematic diagram of Darwin's experiment and guide the students to analyze the single variable principle and the control principle of the control experiment design. Organize students to discuss four experiments in groups, two experiments in each group, and analyze the independent variables, dependent variables, results and conclusions of each experiment. Question: what is the conclusion of Darwin's whole experiment? Ask the question: what is this "impact"? Show the schematic diagram of Bob Jason's experiment, explain the experimental materials (agar and mica), and ask the question: what conclusion can be drawn from Bob Jason's experiment? Ask the question: the influence of the tip can be transmitted to the lower part, so why can it make the two sides of the elongation zone unevenly distributed? Show the schematic diagram of Bayer's experiment and ask the question: Why did Bayer's experiment choose the dark environment? What is the conclusion of the experiment? Show the schematic diagram of winter experiment and ask the question: what is the phenomenon of winter experiment? What is the conclusion of the experiment? When winter put forward the concept of auxin, he did not extract this substance, so that students can understand it and draw certain scientific conclusions on the basis of rigorous logical reasoning, which sometimes requires a certain amount of imagination. According to the above experimental explanation, the reason for the bending growth of plants to light is explained. Different views on the causes of phototropism of plants after 1980s were introduced. Guide students to read the textbook, understand the concept of plant	Read the textbook and learn about the experiments done by scientists. Observe in groups and discuss the experimental results and conclusions. Analyze the experiment, think and answer the questions. Think about the discussion and answer the questions. Think and discuss to understand the chemical nature of auxin. Describe the causes of phototropism in plants. Read the material to understand the dispute. Read the textbook to clarify the concept of plant hormones; Compare the similarities and differences between plant hormones and animal hormones.	The discovery process of auxin is not only a part of learning the history of biological science, but also a part of experimental exploration. Take the history of auxin discovery as a clue, select key historical facts to organize, guide students to experience the process of scientists' exploration and the formation of scientific knowledge, understand how scientists find problems, look for evidence, judge on the basis of rigorous reasoning, and understand the nature of science and the methods of scientific research. Let students recognize that science is constantly developing. Compare the similarities and differences of knowledge before and after contact, and help students improve their ability to summarize.

	hormones, and emphasize that plant hormones, as information molecules, are involved in almost all life activities in the process of plant growth and development. Organize students to summarize and compare the similarities and differences between plant hormones and animal hormones based on the knowledge links in the textbook.		
Production, transportation and distribution of auxin	Guide students to read the textbook and answer the question: where is the main synthesis site of auxin? What is the transportation mode and direction of auxin? What is the distribution of auxin? Guide students to "evaluate the experimental design and conclusion" in the skill training of reading textbooks, and discuss in groups and answer the questions given in the textbooks.	Students read the textbook, think and answer questions. Work in groups to analyze and improve the experiment.	Cultivate students' ability to explore and design experiments and rigorous logical thinking ability.
classroom summary	Lead students to review what they have learned. Guide students to check whether there are errors in column K and column W and whether the questions are answered.	Sort out the knowledge and fill in column L. Check and deepen the knowledge framework of this section.	In the L link, let students summarize what they have learned and improve their ability to summarize and integrate.

(6) Teaching reflection

In this section, the KWL mode of "discovery of plant auxin" teaching, combined with the history of biological science, explores students' "want to know", reproduces the exploration process of scientists in solving biological problems, and cultivates students' scientific thinking.

Students in this class completed the KWL learning form in the process of learning and exploration. First of all, through some phenomena that students are familiar with: sunflowers face the sun, and the leaves in the south are dense, to deeply understand the phototropism characteristics of plants. Students ask questions on the basis of "known" experience: what is the reason for the phototropism of plants? How did scientists find out? Take "want to know" to learn the scientific history of auxin discovery, and let students analyze and summarize the data provided by teachers and draw relevant conclusions. From putting forward problems, analyzing problems, solving problems to extending new problems, re analyzing and solving problems, finally, "rediscovering" the knowledge of plant auxin. Students have experienced the exploration of the answer to "want to know", and have a deep understanding of the experimental methods and scientific thinking in the process of auxin discovery by using the methods of observation, analysis and reasoning.

6. Results and Analysis of Teaching Practice

6.1. Results and Analysis of Changes in Experimental Classes before and after Teaching Practice

Paired sample t-test was conducted on the pre-test and post test data of different dimensions of scientific thinking in the experimental class, and figure 6.1 and table 6.1 were obtained. It can be seen from the figure that after a period of study, the average value of the post test data of the experimental class in different dimensions of scientific thinking has improved by different degrees compared with the pre-test. Through further analysis in table 6.1, it is found that the p value of pre-test and post test data difference in induction and generalization, model and modeling, critical thinking and creative thinking is infinitely close to 0, less than 0.01, and the difference is extremely significant. The p value of the difference between pre-test and post test data in deduction and reasoning was greater than 0.05, and the difference was not significant.

Figure-6.1. comparison of different dimensions of scientific thinking before and after the test in the experimental class

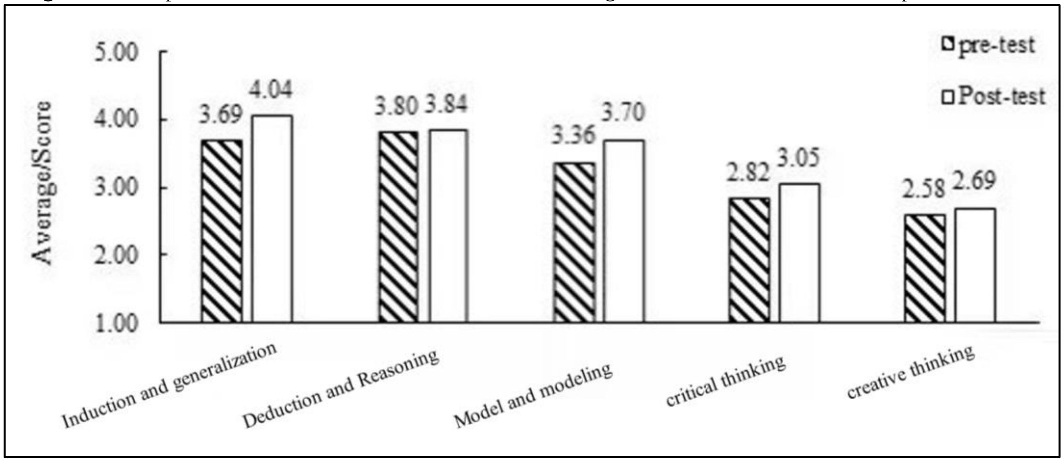


Table-6.1. paired sample t-test of different dimensions of scientific thinking in the experimental class

Dimension	Group	Average	Standard deviation	T	Sig.
Induction and generalization	Post-test	4.04	0.53	7.054	0.000**
	Pre-test	3.69	0.75		
Deduction and Reasoning	Post-test	3.84	0.58	1.350	0.208
	Pre test	3.80	0.65		
Model and modeling	Post-test	3.70	0.65	7.142	0.000**
	Pre-test	3.36	0.80		
Critical thinking	Post-test	3.05	0.56	6.170	0.000**
	Pre-test	2.82	0.68		
Creative thinking	Post-test	2.69	0.73	4.387	0.000**
	Pre-test	2.58	0.75		

Note: ** indicates that the difference between the two groups is extremely significant ($P<0.01$)

Overall, after a semester of learning the module of "steady state and environment" under the KWL teaching mode, the experimental class has made significant progress in induction and generalization, model and modeling, critical thinking and creative thinking, and also made progress in deduction and reasoning, but the progress is not obvious.

6.2. Results and Analysis of Changes in the Control Class before and after Teaching Practice

Paired sample t-test was conducted on the pre-test and post test data of different dimensions of scientific thinking in the control class, and figure 6.2 and table 6.2 were obtained. It can be seen from the figure that after a period of study, the average value of the control class in different dimensions of scientific thinking has increased by different degrees. Through the further analysis in table 6.2, it is found that the p value of the pre-test and posttest differences in model and modeling is less than 0.05, and the difference is significant. The p value of the pre-test and posttest differences in the four aspects of induction and generalization, deduction and reasoning, critical thinking and creative thinking was greater than 0.05, and the difference was not significant.

In general, under the conventional teaching mode, the module of "the discovery process of auxin" is more significant in the cultivation of students' model and modeling, but less significant in the cultivation of induction and generalization, deduction and reasoning, critical thinking and creative thinking.

Figure-6.2. comparison of pre-test and posttest of different dimensions of scientific thinking in the control class

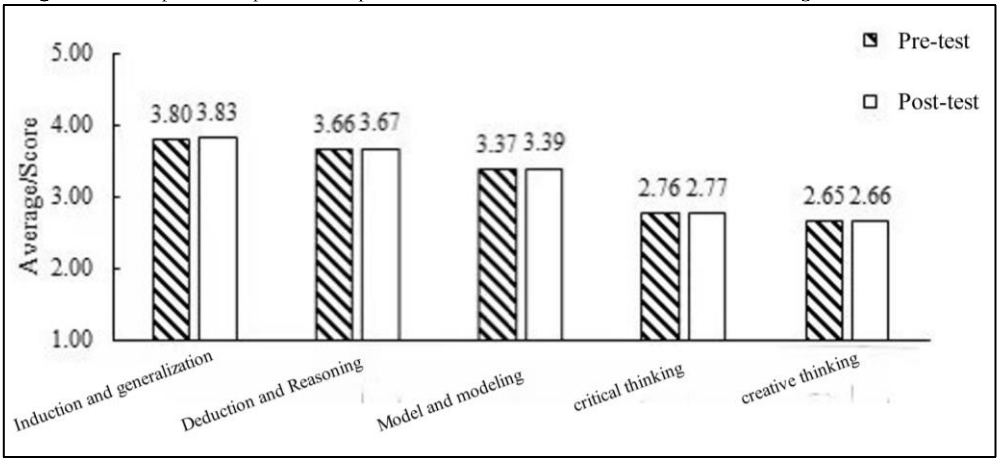


Table-6.2. paired sample t-test for pre-test and posttest of different dimensions of scientific thinking in the control class

Dimension	Group	Average	Standard deviation	T	Sig.
Induction and generalization	Post-test	3.83	0.65	1.759	0.083
	Pre-test	3.80	0.72		
Deduction and Reasoning	Post-test	3.67	0.68	1.425	0.159
	Pre-test	3.66	0.69		
Model and modeling	Post-test	3.39	0.80	2.047	0.045*
	Pre-test	3.37	0.84		
Critical thinking	Post-test	2.77	0.71	1.000	0.321
	Pre-test	2.76	0.71		
Creative thinking	Post-test	2.66	0.70	1.425	0.159
	Pre-test	2.65	0.69		

6.3. Comparison of other Aspects between the Experimental Class and the Control Class

In order to understand the differences between the two classes in different dimensions of scientific thinking, the different dimensions of scientific thinking in the post test of the two classes were analyzed. It can be seen that the average value of the experimental class in each dimension is higher than that of the control class to varying degrees. Through further analysis, it was found that the p value of pre-test and post-test differences in induction and generalization, model and modeling, critical thinking was less than 0.05, and the difference was significant. The p value of pre-test and post-test differences in deduction and reasoning and creative thinking was greater than 0.05, and the difference was not significant.

It can be concluded that in the learning process of auxin discovery, the experimental class performed significantly better than the control class in induction and generalization, model and modeling, and critical thinking, and slightly better than the control class in deduction and reasoning, and creative thinking, but the difference was not obvious.

Table-6.3. independent sample t-test of pre test and post test of scientific thinking in experimental class and control class

Dimension	Group	Average	Standard deviation	T	Sig.
Induction and generalization	Experimental class	4.04	0.53	2.130	0.035*
	Control class	3.83	0.65		
Deduction and Reasoning	Experimental class	3.84	0.58	1.557	0.122
	Control class	3.67	0.68		
Model and modeling	Experimental class	3.70	0.65	2.480	0.014*
	Control class	3.39	0.80		
Critical thinking	Experimental class	3.05	0.56	2.603	0.011*
	Control class	2.77	0.71		
Creative thinking	Experimental class	2.69	0.73	0.202	0.840
	Control class	2.66	0.70		

Note: * the difference between the two groups is significant (P<0.05)

6.4. Summary of Teaching Practice

After the KWL mode teaching in the experimental class and the conventional mode teaching in the control class, through the collation, statistics and analysis of the pre-test and post test data, it is found that students have positive feedback on the application of KWL mode. The experimental class with KWL teaching mode has a slightly higher biological performance than the control class. The experimental class students' feedback in the classroom is more positive, the classroom atmosphere is more active, students' active thinking, learning interest is improved, after a semester, they have accumulated many KWL learning forms, and have a stronger grasp of the knowledge structure system.

In a word, both conventional teaching mode and KWL teaching mode can improve students' biological performance to a certain extent, but the teaching effect of conventional mode is not as good as KWL mode in the cultivation of students' scientific thinking. KWL mode teaching is helpful to cultivate students' scientific thinking, especially to the development of induction and generalization, model and modeling, and critical thinking; KWL mode helps students better study biology.

7. Research Conclusion

Based on the feasibility of the KWL teaching mode to cultivate students' scientific thinking theory, this study investigated the current situation of the cultivation of students' scientific thinking in the second grade of senior high school in the internship school through questionnaire survey and interview, carried out the teaching practice of KWL mode through the educational experiment method, and found that the application of KWL teaching mode to cultivate high school students' scientific thinking is feasible and effective through the analysis of mathematical statistics and other methods. The following conclusions are drawn:

(1) The application of KWL mode in high school biology teaching is conducive to cultivating students' scientific thinking.

(2) KWL mode is conducive to the development of students' induction and generalization, model and modeling, and critical thinking.

(3) KWL teaching mode can help students better study biology.

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