USING 5E INQUIRY BASED TEACHING TO IMPROVE EXPERIMENTAL DESIGN ABILITY FOR MIDDLE SCHOOL STUDENTS

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A thematic paper submitted in partial fulfillment of the requirements
for the Master of Education program in Curriculum and Instruction
Academic Year 2023

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Academic Year	**2023**

ABSTRACT

The objectives of this study were 1) to using 5E inquiry-based teaching to improve the experimental design ability for middle school students and 2) to compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching. The simple group of this study consisted of 30 samples from the first year at Beichen Middle School in Weifang. The research tools included 1) lesson plans and 2) experimental design ability assessment. The assessment questions were designed to assessment four sub-variables in the dependent variable, including the assessment questions were designed to assessment three sub-variables in the dependent variable, including specify the purpose of an experiment ability, state the relationship of variables ability, describe the experimental procedure ability, express the expected results of an experiment ability. The data were analyzed by mean, standard deviation and t-test for dependent sample.

The results revealed the followings:

1. By using 5E inquiry-based teaching and observing students' learning behaviors, it is found that students have improved in clarifying the purpose of the experiment, explaining the relationship of variables, describing the experimental process, express the expected results of the experiment, and the ability of experimental design.

2. Comparing of experimental design ability of students before and after learning with the 5E inquiry-based teaching, it was found that after learning was higher than

before learning by statistically significant at the .01 level. This was consistent with the research hypothesis.

Keywords: 5E inquiry-based teaching, experimental design ability, middle school student

Acknowledgement

I would like to thank my supervisors, Assistant Professor Dr. Phatchareephorn BangKhow and Dr. Phenporn Thongkamsuk, whose rigorous attitude, hard-working spirit, tireless pursuit of scientific research, and dedication to academics have been a model for me to learn from, and a motivation to persevere, advance, and strive for excellence in the past three years. It is also the motivation for me to persist, advance and work hard. In the selection of thesis topics, experimental design, scientific research, every supervision, every instruction, every guidance of the teacher has benefited me a lot, so that my scientific research is carried out smoothly. At the parting moment, when I look back in the twilight, I am grateful to my teachers for their kindness, which is like a lighthouse guiding me on the road of long journey and the direction of my search for life.

At the same time, but also inseparable from the care and help of students and friends. I would like to thank all students for their guidance and help; thank you for your parents and family help and support, in the future, I will work hard to live up to my family's expectations of me.

Yin Hua

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Introduction

Rationale

In the new era, in the face of the problem of unbalanced and inadequate educational development, China has continued to push forward educational reform and innovation. 2010 saw the release of the Outline of the National Medium- and Long-Term Educational Reform and Development Plan (2010-2020), which points out the need to adhere to the principles of moral education as the first priority, emphasizing competence, reforming teaching methods and content, advocating participatory and inquiry teaching, focusing on giving full play to the students' initiative in their learning, and vigorously promoting the all-round development of human beings, promote the all-round development of human beings(Ministry of Education of the People's Republic of China,2022). In response to the call of the new era, the Ministry of Education promulgated the High School Biology Curriculum Standards (2017 Edition). In the newly promulgated curriculum standards, the discipline of biology is defined as the study of the laws and phenomena of life activities, which is categorized under the category of natural sciences and will have an important impact on the production and life of the current human society. Meanwhile, the senior high school biology curriculum requires students to master more basic knowledge on the basis of what they have learned in the junior high school biology curriculum, and to form a scientific way of thinking and an attitude of inquiry. In the Teaching and Learning Suggestions section, it is clearly stated that the contents and methods of teaching and learning activities should be selected according to the important concepts, and all activities should be conducive to promoting students' construction of important biological concepts. At the same time, it is emphasized that students should actively participate in inquiry activities, use their hands and brains more to deepen their understanding and application of the concepts, so that they can have good interpretation and decision-making abilities when facing practical problems and challenges in life. The new curriculum reform

points out that the purpose of education is not only to impart knowledge to students, but more importantly to cultivate their comprehensive quality and practical ability. In other words, students not only need to know what, but also why, and more importantly, how to do; students not only need to learn what they already know, but also learn to collect and process knowledge with their hands and brains, and learn to grow and produce knowledge on their own (Myers and Burgess, 2003). Biology is a natural science based on experiments. Experimentation is an important way to cultivate students' ability in this area. Therefore, we should pay attention to the experimental teaching of biology.

At present, the cultivation of experimental design ability in middle school is not satisfactory. This is not only because of the lack of middle school biology teaching facilities, but also because the teaching methods used are too boring. The application of traditional teaching mode in middle school experimental teaching has certain limitations. For many middle school biology teachers, although the pace of the new curriculum reform is accelerating, in order to improve the students' advancement rate, teachers still mostly use the traditional teaching mode. The so-called traditional teaching mode means that the biology teacher teaches the lesson on the podium and the students bury their heads under the podium to take notes. The advantage of this teaching method is that teachers can enrich students' experimental learning content, and the disadvantage is that students' classroom learning efficiency is low. Although students make a lot of biology notes in the classroom, they can't digest and memorize these contents in the classroom. The new curriculum standard requires reflecting students' subjectivity and emphasizing students' classroom participation. In addition, there are many teaching materials in the new standard that can be used as "discussion questions" in classroom teaching. However, at present, in the process of our classroom teaching, teachers' classroom questions and dialogues are asking questions for the sake of solving problems, not digging deeper into the problems themselves, and still staying in the traditional questioning teaching method (Ding, 2021). The interaction between teachers and students cannot stimulate students to think about the classroom problems and guide them to understand the classroom content (Goodey and Talgar, 2016).

5E inquiry-based teaching provides a necessary path for middle school experimental learning. The development achievements of life science in recent decades are remarkable, and it has become one of the most active disciplines in the 21st century. This puts forward higher requirements for the quality of personnel training in the field of life science in China, and the reform of biology teaching in the field of basic education in China needs to keep pace with the times. Ni (2022) pointed out the 5E inquiry-based teaching is an important education model in the field of science education. It was put forward by the American Institute of Biological Sciences Curriculum Research (BSCS) on the basis of Atkin Kailas learning ring. Its purpose is to help students realize concept transformation and scientific concept construction (Zhu,2022). This teaching model has been applied in the overall curriculum design of BSCS since the late 1980s and has been highly recognized. With this model, students can fully realize the importance of experimental design ability and actively participate in them. Therefore, applying the five components of 5E inquiry-based teaching to high school biology teaching is conducive to improving students' learning motivation and experimental design ability.

To sum up, 5E inquiry-based requires teachers to choose the content of experimental design ability, constantly improve their professional quality, combine the actual situation of students and their own teaching experience, efficiently and flexibly use this model to build interesting biological classes, internalize its teaching concepts into experimental teaching, and promote it to more biological theory classes, experimental classes or review classes. 5E inquiry-based has a positive impact on senior high school students' further improvement of biological scientific thinking, can mobilize students' enthusiasm for classroom learning to a certain extent, effectively promote the process of active interaction between teachers and students, and improve senior high school students' biological scientific thinking, so it is worth applying in senior high school biology classroom teaching. Therefore, the researcher is interested in using the 5E inquiry-based teaching to organize the processes of teaching and learning in order to improve the experimental design ability of middle school students in a way that is progressive and can be used in a more effective way.

Objectives

1.To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Research Hypothesis

After the implementation based on 5E inquiry-based teaching, the students' experimental design ability has been improved obviously.

Scope of the Research

Population and the Sample Group

Population

There are 120 students in the first year at Weifang Beichen Middle School, divided into 4 classes with 30 students in each class.

The Sample Group

Through cluster random sampling, 30 students from Class 2, Grade 1 with mix abilities (strong, medium, and weak) in Weifang Beichen Middle School.

The Variables

Independent Variables

5E inquiry-based teaching

Dependent Variable

experimental design ability

Content

The purpose of this study is to improve the experimental design ability by applying the 5E inquiry-based teaching in biology courses. This course is divided into the following four learning units:

1. learning unit 1: Structure and function of cell membrane (3 hours)

2. learning unit 2: Active transportation and endocytosis, exocytosis (3 hours)

3. learning unit 3: Enzymes that reduce the activation energy of chemical reactions (3 hours)

4. learning unit 4: Photosynthesis and energy conversion (3 hours)

Time

The study period from March to October 2023 is divided into the following phases:

1. Develop proposal research in March 2023.

2. Modified and completed 1) the teaching plan of biology course based on 5E inquiry-based teaching and 2) the knowledge assessment based on 5E inquiry-based teaching from June to August 2023.

3. Experimental studies will be conducted from August to September 2023.

4. The formal study will be conducted from August to September 2023.

5. Summarize the research and complete the research paper, which will be published in October 2023.

Advantages

1. For students. The 5E inquiry-based teaching meets the requirements of the new curriculum standard. The core of this teaching is student-centered, which can enhance the interactivity of students' experimental design learning, enjoy the experimental design ability experience of interactive discussion with peers, stimulate students' enthusiasm for learning and exploration, help maintain and transfer biological knowledge and skills, and enhance students' awareness and ability of self-learning.

2. For teachers. Through the introduction of 5E inquiry-based teaching in the classroom, biology students can be encouraged to cooperate with each other without the guidance of teachers, put forward exploratory questions, help students understand their own experience, let students create interpretation models based on the evidence obtained from the exploration, try to answer questions, help students use the knowledge learned to explain new things or ideas, and finally help teachers to evaluate students' experimental design ability progress and learning effects.

Definition of Terms

5E Inquiry-Based Teaching: 5E inquiry-based teaching is a constructivist teaching model developed by R. Bybee, one of the main researchers of BSCS. This mode emphasizes the student-centered approach and solves problems through investigation and experiment. It emphasizes to promote students' understanding of scientific concepts and knowledge construction through group cooperative learning. The 5E inquiry-based teaching is divided into five learning stages: engagement, exploration, explanation, elaboration and evaluation. Because the five learning stages start with "E", they are also called 5E inquiry-based teaching.

Step 1 Engagement, this link is the starting link of the 5E inquiry-based teaching. In order to attract students' interest in learning tasks and stimulate students to explore actively.

Step 2 Exploration, this link is the central link of the 5E inquiry-based teaching. Teachers can guide students to explore according to the cognitive conflict generated in the previous link.

Step 3 Explanation, this link is the key link of the 5E inquiry-based teaching. At this stage, students should focus their attention on the display and analysis of the inquiry process and results, provide them with an opportunity to show their understanding of the concept, as well as the mastery of skills or the use of methods, and let students try to explain their understanding of the concept with their own understanding.

Step 4 Elaboration, under the guidance of the teacher, continue to develop the students' understanding and application skills of concepts, expand the basic connotation of concepts, establish some connection with other existing concepts, and explain new situations or new problems with new concepts.

Step 5 Evaluation, at this stage, teachers and students use formal or informal methods to evaluate students' understanding and application of new knowledge.

Experimental Design Ability: It refers to the understanding of the general process of scientific research, which includes a series of elements ranging from the formulation of a question, the formation of a hypothesis, and the selection of variables, to the analysis of the results and the writing of a paper. It shows

researchers the whole picture of how to conduct scientific research and tries to solve the problems of the whole process of scientific research. In this paper, based on the 2017 edition of the General High School Biology Curriculum Standards, the experimental design ability in biology is defined as the experimenter's design ability to apply scientific knowledge and principles to the overall conceptualization and planning of an experiment, and in conjunction with Zhang (2020), the experimental design ability is decomposed into four abilities: 1) specify the purpose of an experiment ability, 2) state the relationship of variables ability, 3) describe the experimental procedure ability,4) express the expected results of an experiment ability, and the four abilities are organic whole, with a strong synthesis.

Middle school students: Middle school students refer to students receiving secondary education, generally aged about 11-19 years old, including junior high school students and senior high school students. Junior high school is the last three years of nine-year compulsory education. At the end of the third year of junior high school, there is a joint examination. If you pass the joint examination, you can get your junior high school diploma. High school is not a compulsory education stage. Junior high school graduates need to take the junior high school academic level examination and enroll them into senior high school on a selective basis. Ordinary high school is divided into three academic years. In this study, middle school students refer to students who study in the first academic year of ordinary high school.

Research Framework

Using 5E inquiry-based teaching to improve experimental design ability for middle school students. The research concept framework is as follows:

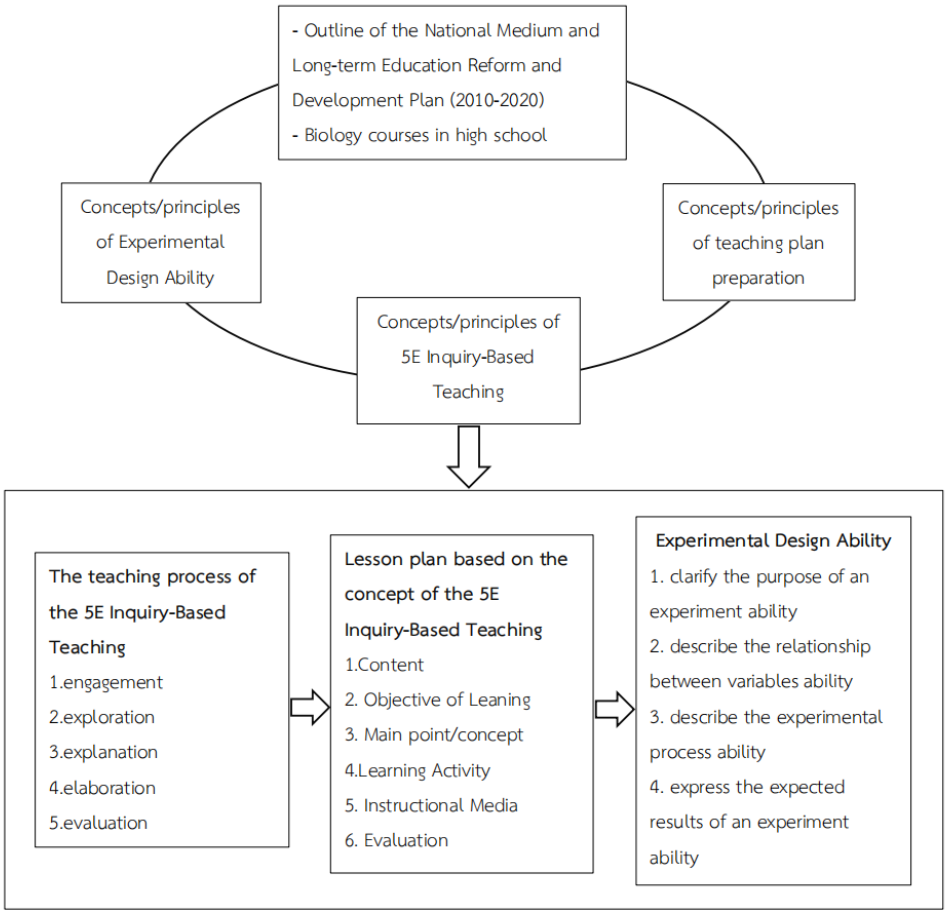

Figure 1.1 Research Framework

Chapter 2

Literature Review

Using 5E inquiry-based teaching to improve experimental design ability for middle school students, the following literatures were studied.

1. 5E inquiry-based teaching
2. Experimental design ability
3. Middle school course
4. Relevant research

The details are as follows:

5E Inquiry-Based Teaching

The 5E inquiry-based teaching is a constructivist instructional developed by the Biology Curriculum Study (BSCS) in the United States that has attracted a great deal of attention in the field of science education. Since the late 1980s, the 5E inquiry-based teaching has been used in the general curriculum design of the BSCS and has occupied a very important position. It describes an instructional procedure that can be used in the general curriculum, a subject-specific course, or a specific lesson, and is an effective instructional model and teaching method that is dedicated to arousing students' interest.

The meaning of 5E Inquiry-Based Teaching

With the development of cognitive science, especially the development of misconception and conceptual change research, the American Institute of Biology Curriculum Research (BSCS) has developed a research project for science and health courses in primary schools. BSCS believes that to carry out effective teaching and help students construct scientific concepts, it is not only necessary to emphasize the process of inquiry, but also more important to understand students' pre-scientific concepts of specific teaching content. This requires teachers to create specific situations or put forward corresponding questions to let students show and expose existing concepts, and then explore on this basis. Therefore, in 1989, BSCS revised

and improved the Atkin-Karplus learning loop model, and proposed a 5E inquiry-based teaching based on constructionist theory and concept transformation theory. This model includes five links, namely, attraction, exploration, interpretation, migration and evaluation. It constructs classroom teaching into a step-by-step exploration activity link, fully arouses students' enthusiasm for learning, investigation, experiment, problem solving and other processes, and fully transforms pre-scientific concepts and misconceptions.

Bybee R W. et al. (2006, pp.88-98) believed that 5E inquiry-based teaching is a teaching model based on constructivism theory developed by the American biology curriculum research. This teaching model was initially widely used in the curriculum design of biology by western educators, and was widely praised. Compared with other teaching modes, 5E inquiry-based teaching is an inquiry teaching, which is of great significance to cultivate students' core literacy. The 5E inquiry-based teaching is superior to the traditional teaching mode in teaching effect, and is recognized by teachers and loved by students; the 5E inquiry-based teaching is conducive to improving students' participation in the classroom, helping students to summarize in time, and has a positive impact on the improvement of students' academic performance and core literacy.

Bybee R W. (2014, pp.10-11) believed that 5E inquiry-based teaching is a teaching mode under the guidance of inquiry teaching method, which tends to be student-centered and solve problems through investigation and cooperation. It emphasizes to promote students' construction of new knowledge through group cooperation, exchange, discussion and learning. The 5E inquiry-based teaching is divided into five learning stages: Engagement, Exploration, Expansion, Elaboration and Evaluation. The research results show that the 5E inquiry-based teaching has a positive impact on teaching. It can not only improve students' interest and confidence in learning, improve their learning ability, but also promote students' learning achievements.

Ong, E. T. et al. (2018, pp.348-360) argues that the structure of teaching sequences using energy change backgrounds follows the characteristics of each stage in the 5E inquiry-based learning, namely participation, exploration, explanation, elaboration

(expansion), and evaluation. In contrast, traditional teaching methods are teacher centered. Essentially, the 5E inquiry-based teaching or 5E consists of the following stages: participation, exploration, explanation, refinement, and evaluation. Each stage has specific teaching functions that contribute to the coherent teaching of teachers and the formation of learners' scientific and technological knowledge.

Wu Liwen (2022, p.91) pointed out that the 5E inquiry-based teaching is the process of guiding and inspiring students to fully use the multidisciplinary knowledge and skills they have mastered to explore ways and methods to solve problems in the real problem situation created by teachers, and constantly modify and improve the plan through teacher-student interaction and discussion, and finally construct a new multidisciplinary knowledge system, so as to achieve the goal of cultivating interdisciplinary research and innovation talents. The teaching practice in recent three years has proved that the 5E inquiry-based teaching can effectively stimulate students' initiative and enthusiasm in learning, deepen their understanding and mastery of interdisciplinary new knowledge, improve their practical application ability, and significantly improve students' scientific research and innovation ability.

Zhu Kai (2022, p.99-101) pointed out that the concept of structure and function is one of the concepts of life, which can be simply defined as structure determines function, and function needs to adapt to structure. The 5E inquiry-based teaching consists of five parts: introduction, exploration, interpretation, transfer and evaluation. It is student-centered and flexible. It can improve students' enthusiasm for learning, help students understand important concepts and are of great benefit to junior high school biology teachers to cultivate students' structure and function view.

To sum up, the application of 5E inquiry-based teaching can effectively improve students' academic literacy and help develop students' comprehensive quality and ability. 5E inquiry-based teaching is a constructivist teaching model developed by Bybee, one of the main researchers of BSCS. This mode emphasizes the student-centered approach and solves problems through investigation and experiment. It emphasizes to promote students' understanding of scientific concepts and knowledge construction through group cooperative learning. The 5E

inquiry-based teaching is divided into five learning stages: engagement, exploration, explanation, elaboration and evaluation. Because the five learning stages start with "E", they are also called 5E inquiry-based teaching.

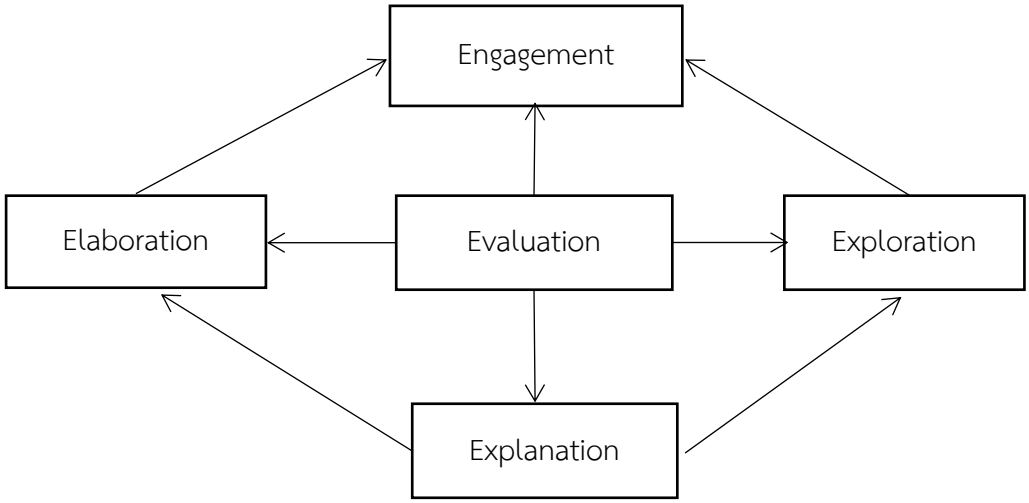

Figure 2.1 All links of 5E inquiry-based teaching

Theoretical Basis of 5E Inquiry-Based Teaching

Peng Cong (2015, pp.54-57) believed that the 5E inquiry-based teaching originated from the concept transformation theory. The so-called concept transformation is learning, which is the process of changing, developing and reconstructing students' original concepts, and is the process of learners' transformation from pre-scientific concepts to scientific concepts. In order to promote students to realize concept change, concept change teaching should be carried out. To this end, teachers must fully understand the original knowledge and experience background of students' relevant disciplines, understand what wrong concepts students have, and make full use of students' original concepts to create cognitive conflicts (situations) in teaching, as an opportunity to trigger students to conduct concept change learning. Because to change students' wrong concepts, it is invalid to only tell students the "correct" concept. Only in the stimulating situation, in the fierce collision between students' preconceptions and scientific concepts, can the conflict between preconceptions and scientific concepts be resolved and the transformation from preconceptions to scientific concepts be realized.

The study of conceptual change began in the 1970s. PosNER, G. J. et al. (1982, pp.211-227) and others drew on Piaget's cognitive constructivism theory and the thoughts of contemporary philosophers such as Kuhn and Lakatos. In the second issue of the journal of Science Education, Vol. 66, they jointly published the article "Correspondence of Scientific Concepts: Establishment of Conceptual Change Theory", and put forward the famous conceptual change model (CCM). The model defines concept transformation as the process of transforming core and organizational concepts from one conceptual system to another incompatible conceptual system. Conceptual transformation theory believes that there are two types of conceptual transformation: one is assimilation that is, using existing concepts to explain new phenomena; the second is adaptation, which reconstructs the core concepts for the successful understanding of new phenomena, which is a fundamental change. Four conditions are needed to transform the original concept into a scientific concept, namely dissatisfaction with the original concept, comprehensibility of the new concept, rationality of the new concept and effectiveness of the new concept.

Liu Enshan (2019, pp.43-52) believes that the theoretical basis of the 5E inquiry-based teaching is based on constructivist theory. Constructivism is a philosophical theory developed from cognitivist, which was first proposed by Swiss psychologist Jean Piaget. The basic viewpoint of constructivism is: the world exists objectively, and learners construct new knowledge based on their original experiences, psychological structures and beliefs. Constructivist learning theory points out that the learning process of students is a process of actively constructing learning. Students acquire knowledge not through traditional passive indoctrination, but with the creation of teaching situations and the help of others, using rich learning resources, starting from students' old knowledge and existing experience, to carry out effective knowledge acquisition. Meaningful self-constructing process; Constructivist learning theory takes" situation, collaboration, communication and meaning construction" as the four elements of learning.

Constructivism is mainly influenced by the thoughts of several famous educators: (1) Dewey's empirical learning theory. Dewey stressed that education must be based on experience. Education is the growth of experience and the

transformation of experience. Students produce problems from experience, and problems inspire them to explore knowledge and generate new ideas; (2) Vygotsky's thought, Vygotsky emphasizes that individual learning is carried out under a certain historical, social and cultural background, and society can play an important role in supporting and promoting the development of individual learning. (3) Piaget's theory, Piaget believes that knowledge is neither from the subject nor from the object, but is constructed in the process of interaction between the subject and the object, that is, assimilation and adaptation. (4) Bruner's discovery learning, etc.

Ulukaya Oteles (2020, p.4). pointed out that learning models can effectively enable learners to be proactive and achieve meaningful learning throughout the entire educational process. Among these models, the 5E inquiry-based learning developed based on constructivist learning methods provides multiple possibilities for learners and mentors. The aim of this study is to determine the impact of using the 5E inquiry-based learning in social research on students' academic performance, as well as their views on the model.

Boakye, S. and Nabie, M. J. (2022, pp.14-35). argue that this study is based on constructivism. This theory advocates positive teaching techniques and is widely praised as a learning theory that encourages students to learn independently. Its principle is to explore understanding, as understanding can increase and transform into higher-level thinking based on experience. The 5E inquiry-based teaching has all the characteristics of constructivism and provides opportunities for learners to participate by involving them in activities, enabling them to build their own understanding. Through this approach, teachers promote and guide students to understand the knowledge they have learned.

Wu Liwen (2022, p.91) believes that constructivism learning theory emphasizes that, on the basis of students' existing experience, knowledge construction is promoted through the connection between knowledge, and new knowledge is obtained. Based on constructivism theory, it is implemented in high school mathematics teaching. Situation-based and problem-oriented exploratory and experiential teaching mode is conducive to guiding students to accumulate basic activity experience in cooperation and exchange, and improve knowledge skills and

core mathematical literacy, So as to promote the reform of high school education mode The 5E inquiry-based teaching integrates constructivism theory into the teaching of mathematical modeling in senior high school, and presents the implementation path of the 5E inquiry-based teaching with specific examples in senior high school textbooks, providing reference for the organization and practice of senior high school mathematical activities.

Yang Xingjie (2022, pp.2-4) believed that the 5E inquiry-based teaching originated from Bruner's discovery teaching theory. Jerome Seymour Bruner is a famous cognitive psychologist and educational psychologist in the United States. He has made outstanding contributions in the field of cognitive psychology and is known as the pioneer of cognitive psychology. Bruner believes that learning is an active process of forming cognitive structure, not a passive stimulus-connection reaction. Learners should actively acquire knowledge as the main body of learning, and combine the newly acquired knowledge with the existing cognitive structure to form a complete knowledge system. Bruner's theory is often called cognitive discovery theory, which embodies Bruner's understanding of teaching methods. It is of great significance to education all over the world and promotes the reform of education.

This study is based on this theory and provides theoretical support for the innovation of classroom teaching methods. Based on the principle of student-centered teaching, situation-based teaching and research-based teaching based on the 5E inquiry-based teaching, in the process of experimental teaching, students can use a variety of teaching methods to learn in combination with a variety of learning methods, increase the interest of the classroom and improve the activity of students.

Cruz, J. N. D. et al. (2022, p.34) believed that there appears to be a gap between the idea of Inquiry-Based Learning and its execution, with online lessons for the restructured 5E inquiry-based being more favorable to developing mathematical thinking skills than knowledge and skills. The study implies that in the New Normal, additional materials still needing with inquiry-based teaching and learning. Learning can be assessed in partnership with the community to guarantee that learners learn regardless of the current learning delivery modality.

To sum up, the 5E inquiry-based teaching guides students to learn independently, focuses on cultivating students' meaningful learning, and emphasizes students' participation, interaction, active learning and independent investigation. After consulting relevant literature, people believe that the theory is based on constructivism theory and concept change theory.

Teaching link of 5E Inquiry-Based Teaching

The 5E inquiry-based teaching method, which originated from the teaching of biology, is a constructivist teaching model developed by the American Biology Curriculum Research (BSCS), and has been highly concerned by the educational community because of its complete practicality. It is the mainstream teaching method in the American science classroom. The five "E" are specifically Engagement, Exploration, Expansion, Elaboration and Evaluation. Because the five learning stages start with "E", they are also called 5E inquiry-based teaching. For the teaching tasks and specific application methods of each link, different scholars put forward their own the opinion of.

Duran, L. B. and Duran, E. (2004, pp.49-58) believe that the 5E inquiry-based teaching includes five steps: participation, exploration, exploration, refinement, and evaluation. The first step is to invest. In the first stage of this cycle, the teacher's purpose is to evaluate students' previous knowledge and/or identify potential misunderstandings. This student-centered stage should be a motivational stage that can generate more desire to learn about upcoming topics. The second step is exploration. After promoting psychological attention to concepts during the participation stage, the exploration stage now provides students with a common and specific learning experience. This stage is also student-centered and actively exploring. The role of a teacher is as a facilitator or advisor. Encourage students to learn in a collaborative learning environment without direct guidance from teachers. The third step is to explain. The explanation stage enables students to describe their understanding and ask questions about the concepts they are exploring. It is highly likely that new problems will arise. The explanation stage is an important and brainstorming part of the 5E inquiry-based course. Firstly, you need to have the opportunity to express your explanations and ideas. Therefore, the initial part of the

explanation stage is when the teacher acts as a facilitator, requiring students to describe and discuss their exploratory learning experiences. The fourth step is to refine. Activities in this stage should encourage students to apply their new understanding of concepts while strengthening new skills. Students are encouraged to check their understanding with their peers or design new experiments or models based on the new skills or concepts they acquire. Students can conduct additional surveys, develop products, share information and ideas, or apply their knowledge and skills to other disciplines. This is a great opportunity to integrate science with other content fields. The fifth step is to evaluate. In this regard, both formal and informal evaluation methods are appropriate and should be included. In inquiry-based courses, evaluation should be seen as an ongoing process, where teachers observe students as they apply new concepts and skills and seek evidence of changes or modifications in their thinking. Students may also have the opportunity to conduct self-assessment or peer evaluation. However, the assessment may also include a summative experience, such as quizzes, exams, or writing assignments.

Sen, S. and Oskay, O. O. (2017, pp.1-9) pointed out that the 5E inquiry-based learning cycle model consists of five exploration stages. They are: participating, exploring, explaining, elaborating, and evaluating. The first stage of the 5E inquiry-based learning, namely the participation stage, is the most important stage of the model. In the stage of examining previous knowledge and stimulating curiosity, the knowledge gained by students in the previous years is revealed. In the exploration stage, students are proactive, finding possible answers to questions they are interested in through research and questioning. During the presentation stage, the teacher's work is very heavy. They teach students the concepts formed in the first two stages through questioning, connect chemistry with real life, and attempt to eliminate students' misunderstandings through discovery and explanation. During the elaboration stage, students have the opportunity to apply their knowledge to new environments and apply it to real-life situations. The final stage is the evaluation stage. At this stage, different complementary measurement and evaluation techniques are used to determine whether or to what extent the target benefits have been achieved at the beginning of the course. This stage is important in two

aspects. It ensures that students demonstrate their learning status and development, and receive feedback. It also ensures that teachers see the level of development of students and that they have achieved their teaching objectives. The evaluation is not only conducted at the end of the course, but also throughout the entire process.

D'Acunto, I. et al. (2018, pp.275-278) pointed out that teachers need to implement five stages of learning in their instructional activities: Engage, Explore, Explain, Interpret, and Evaluate. Engage" utilizes "mysteries" to capture students' attention and lead them to ask initial inquiry questions. Explore" allows students to plan experiments and collect observations and data. The 'Explain' stage allows teachers to make sense of the data and draw on previous scientific ideas to try to answer the inquiry question. In the Extension stage, they apply the conceptual understanding gained to solve another problem. In the Assessment stage, students assess their understanding and skills with the help of the teacher.

Singh, J. (2020, pp.867-875) believes that 5E inquiry-based teaching consists of five steps: participation, exploration, explanation, elaboration, and evaluation. The first step is the participation stage: during this stage, teachers establish good connections with students. Some random questions are designed to determine students' knowledge of this topic based on their previous knowledge. During the participation stage, teachers attempt to increase students' attention, interest them, and prepare them for learning. This gives students the opportunity to connect their previous knowledge with their current learning experience. This process lasts approximately 15 to 20 minutes. The second step is the exploration stage: in this stage, the teacher's goal is to create a learning environment for students, enabling them to design and plan experiments, create charts, record data, observe scientific processes, propose hypotheses, discover results, and organize their findings. Teachers only provide relevant ways to understand concepts, provide feedback, and evaluate the level of understanding. The third step is the explanation stage: this stage is centered around the teacher. Students need appropriate guidance and guidance. It enables students to understand concepts. They describe the topic and ask questions. The teacher clarified the students' doubts. Teachers basically use textbooks as the main teaching materials and use other reference books to clarify the topic in more

detail. This stage takes more time than other stages. The fourth step is the elaboration stage: in this stage, give students some activities to understand their ability to execute specific chapters in different ways. This helps teachers understand students' understanding of the topic. The fifth step is the evaluation stage: during this stage, students ask them any other questions related to the chapter or topic. The teacher gave them an assignment sheet to evaluate their knowledge. The activities in the evaluation stage are also used by teachers for formative and summative evaluations of student learning.

Han, Maozhen, Huang Binbin and Yan Zhang (2021, pp.119-121) pointed out that the 5E inquiry-based teaching is an advanced heuristic education model that uses real cases and practical operations to attract students' interest in learning, is based on problems, takes students as the main body of teaching activities, and emphasizes the teacher's guiding role. The 5E inquiry-based teaching generally includes the following five main links: step1 is to attract (Engagement), which is the starting point of the 5E inquiry-based teaching, requiring teachers to play a guiding role by creating a suitable situation to attract students' attention. Step2 is Exploration. As the main stage of the 5E inquiry-based teaching, the exploration stage can give full play to students' initiative. Teachers, as instructors, need to organize students to conduct research, experimental verification and other exploratory activities in this stage, guiding students to discuss the correct concept. Students as the main body of teaching activities, in this stage through the students, as the main body of teaching activities, form concepts, generalizations and explanations through various exploratory activities in this stage. step3 is Explanation. Teachers need to explain the phenomena observed by students through lectures, define the key concepts accurately, and provide the scientific terms involved in the concepts for students to discuss. Students need to describe and explain the phenomena observed in the previous phase and draw conclusions in conjunction with the teacher's explanation. step4 is Elaboration. Elaboration is a continuation of explanation, in which the teacher provides new situations and questions for students to expand and consolidate what they have learned. Students explain new scientific problems by discussing and combining the scientific concepts acquired in the previous activity.

The acquired knowledge is consolidated by practicing, verifying and applying the theoretical knowledge. Step5 is Evaluation. Evaluation is the final part of the 5E inquiry-based teaching, and the main task is to use multivariate evaluation to feedback students' learning results. The main task is to feedback students' learning effect by using multi-element evaluation, including but not limited to the evaluation of the main teacher, students' self-evaluation of learning effect, and the evaluation of the students. The main task is to use multi-element evaluation to feedback students' learning effect, including but not limited to the evaluation of the main teacher, students' self-assessment of learning effect and group mutual evaluation. This includes, but is not limited to, the teacher's assessment, students' self-assessment of learning outcomes and group assessment. The main task is to use multivariate evaluation to feedback students' learning effects, including but not limited to the evaluation of the lecturer, students' self-assessment of learning effects and group mutual evaluation. The evaluation focuses on the inquiry process and the degree of students' participation.

Qiu Benyu (2022, p.39) pointed out that the 5E inquiry-based teaching consists of the following five steps; Step 1 is Engagement, which refers to attracting students' attention to the teaching task, usually in the form of a problem situation set by the teacher, and the problem is designed according to students' prior knowledge and is closely related to their real life. Step 2 is Exploration, which is conducted after students' desire to learn is aroused through an introduction session. Under the guidance of the teacher, students are excited to complete the exploration task and actively solve the problems raised by the teacher. Step 3 is Explanation, in which students give preliminary explanations of the problems and results of the investigation in their own words, and the teacher adds to them to help them further understand the concepts. Step 4 is Elaboration, which refers to the further deepening of knowledge based on the inquiry and explanation sessions. Step 5 is Evaluation, which refers to the evaluation of students' learning outcomes.

Zhang Congcong. (2022, p.127) pointed out that the 5E inquiry-based teaching consists of five teaching steps: Step 1 is Engage: to stimulate students' interest in participation and inquiry; Step 2 is Explore: to carry out in-depth and continuous

inquiry; Step 3 is Explain: to test whether they really understand what they have learned; Step 4 is Elaborate: to use what they have learned to promote the transformation of knowledge and concepts; Step 5 is Evaluate: to provide authentic feedback on students' learning through multiple evaluations. Combining the 5E inquiry-based teaching with the requirements of practical activities in the teaching process in the basic concept of the new curriculum standard; we should carry out practical research on the biological activity class, and explore the relevance between the activity class and the 5E inquiry-based teaching. The students' core literacy level has been greatly improved through the learning in the high school biological activity class under the 5E inquiry-based teaching. The results of student self-evaluation and mutual evaluation show that students' interest in biology learning is significantly improved through the learning of biological activity class under the 5E inquiry-based teaching. In the practical activities of group cooperation, students actively participate in cooperation and actively explore problems. Their sense of cooperation and exploration ability has improved, and their awareness of problem solving has changed better, and they have gradually formed the habit of continuous exploration.

To sum up, the 5E inquiry-based teaching is an important participatory, inquiry-based teaching model that focuses on the important role of the learner. It is student-centered, contextualized, teacher-led, and inquiry guided by the teacher investigation and through the joint completion of teacher explanation and student sharing, it continuously promotes the consolidation of old knowledge and the transfer of new knowledge. It consisted of 5 steps of teaching, as detailed below**.**

Table 2.1 The process of the 5E Inquiry-Based Teaching

5E Inquiry-Based Teaching					
Author	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Step 5**
Lena Ballone Duran and Emilio Duran 2004	Engagement	Exploration	Explanation	Elaboration	Evaluation
Senol Senl and Ozge Ozyalcin Oskay 2017	Engagement	Exploration	Explanation	Elaboration	Evaluation
Immacolata D'Acunto et al. 2018	Engagement	Exploration	Explanation	Elaboration	Evaluation
Jogendra Singh 2020	Engagement	Exploration	Explanation	Elaboration	Evaluation
Qiu Pengyu 2022	Engagement	Exploration	Explanation	Elaboration	Evaluation
This research detail	Engagement	Exploration	Explanation	Elaboration	Evaluation

Table 2.2 Detailed Interpretation of 5E Inquiry-Based Teaching

Abbreviation	Teaching link	Teaching task	Teaching strategy
E	Engagement	Attract students' interest in learning tasks and stimulate students to explore actively	Emphasis on stimulating students' interest in learning by creating problem situations
E	Exploration	Based on the cognitive conflict generated in the previous session, students are guided to conduct an inquiry	Teachers should pay attention to observation, listening, and give appropriate prompts and guidance to understand the process and depth of students' inquiry, while avoiding students from drawing conclusions too quickly
E	Explanation	Focus students' attention on the process of inquiry and the presentation and analysis of results	Provide opportunities for students to demonstrate their understanding of concepts and their mastery of skills or application of methods, and allow students to try to explain their understanding of knowledge in terms of their own understanding

Table 2.2 Detailed Interpretation of 5E Inquiry-Based Teaching (continue)

Abbreviation	Teaching link	Teaching task	Teaching strategy
E	Elaboration	Students will develop the ability to understand and apply knowledge, expand the basic connotations of knowledge, make certain connections with other existing knowledge, and use new knowledge to explain new situations or problems.	Students are guided to use the expertise they have just learned as much as possible so that they can not only answer new situations and questions; they can also deepen their understanding of the new knowledge.
E	Evaluation	Ensure the direction of student activities or encourage students to reflect on the research process	Use formal or informal assessment methods to assess students' understanding and application of new knowledge

These five-teaching steps links are relatively independent and interconnected, forming a closed loop of scientific classroom teaching. Behind each teaching link lies its unique teaching concept and value. Each link does not propose or stipulate a certain teaching method, but more embodies the teaching concept or characteristics. When guiding teachers in the design and teaching of science subjects, they should focus on the nature of the subject, guide students to think and learn like scientists, guide students to deeply understand scientific concepts, cultivate students' scientific inquiry ability, and help students realize concept transformation and construct scientific concepts.

Characteristics of 5E Inquiry-Based Teaching

Regarding the characteristics of the 5E inquiry-based teaching, different scholars have analyzed them from different angles:

Duran, L. B. and Duran, E. (2004, pp.49-58) pointed out that implementing exploratory teaching is an important theme in national science education reform documents such as the 2016 Plan: Science for All and the National Science Education Standards. These reports believe that exploration should become the core strategy of all science courses. The use of learning loops in the classroom can help promote exploratory practice, as learning loops focus on constructivist principles, emphasize the interpretation and investigation of phenomena, use evidence to support conclusions, and experimental design. Although there are several different learning cycles, one method emphasized in this article that supports exploratory teaching is the 5E inquiry-based teaching. This article also discusses the application of this model in several science education professional development projects. Taslidere, E. (2021, pp.215-238) explored Inquiry-Based Instructional approaches as a technique for producing student attention in science. Inquiry was a procedure that Students used to decide indecision. Grounded in the work of John Dewey, inquiry was compulsory a person to practice philosophical and perilous thinking assistances. The 5E inquiry-based learning helps to stimulate students' learning motivation, covering various activities in which students control the learning process themselves. In addition, this learning model also contributes to the persistence of information and students' academic performance. This learning mode can be used for various courses.

Shi Mei (2019, pp.150-151) discussed the Sanction on the consequence of Inquiry Learning in the Sciences. She serrated out that although people might expect different things/practices when they referred to inquiry-based learning, there were decisive Characteristics that required being nearby, including an integrated prospectus across regulation, a problem-based teaching room, and deliberation to skills enlargement. The 5E inquiry-based teaching has the scientific nature of teaching guiding ideology; Multi-segmental and practical structure of teaching process; Diversity of teaching methods; Timeliness and pertinence of teaching evaluation; The

operability of the teaching model and other characteristics, put forward that in the high school biology teaching model of our country, we should strengthen the systematic learning of the concept of physical education knowledge and the practical application of knowledge, the transformation of the teaching process structure from three-stage to multi-stage, the construction of a comprehensive teaching model, the establishment of a perfect classroom teaching evaluation mechanism and other strategies. It is expected to provide certain theoretical and practical basis for promoting the development of biology teaching model in China.

Zhang Jing (2022, p.68) point that the traditional teaching mode can no longer meet the needs of the country, society and students' development, so it is necessary to actively reform and innovate the teaching mode. 5E inquiry-based teaching is composed of five links: introduction, inquiry, interpretation, transfer and evaluation. It is a kind of inquiry teaching mode based on constructivism theory. It not only pays attention to the process of students' independent inquiry of knowledge, but also pays attention to the cultivation of students' inquiry ability and cooperation consciousness. This teaching mode has changed the traditional situation of "teachers teach and students listen", is committed to stimulating students' interest in learning, emphasizes the two-way interaction between teachers and students in the classroom, and creates a good learning atmosphere for students.

Zhang Luwen (2022, pp.257-260) point that traditional teaching mode pays attention to knowledge imparting and ignores the development of students' scientific thinking quality. As a teaching mode providing flexible and diverse teaching links, 5E inquiry-based teaching has great advantages in improving students' achievements and scientific thinking quality. It is of great significance to apply 5E inquiry-based teaching to teaching research.

Luan Xinjing (2022, pp.178-179) believed that 5E inquiry-based teaching is an inquiry teaching mode with" attraction "," inquiry "," explanation "," transfer "and" evaluation "as the main teaching procedures. The core of" 5E inquiry-based teaching "is to focus on students' inquiry activities and emphasize students' independent construction of knowledge. In the inquiry activities, students can not only acquire scientific knowledge, but also enhance the awareness of inquiry and develop

comprehensive abilities such as teamwork and language expression. With the continuous development of the new curriculum reform, the theoretical and practical research of the teaching model has also shown a trend of prosperity. In order to meet the requirements of the new era for talent cultivation, the inquiry teaching model advocating active independent learning, cooperative learning and inquiry learning has been placed in an important position.

To sum up, based on the above scholars' views, it can be found that the 5E inquiry-based teaching constructs a complete teaching process, covers all aspects of classroom teaching, and forms a closed teaching cycle. 5E inquiry-based emphasizes clear teaching objectives, and each module is gradually promoted for how to achieve the teaching objectives. Compared with traditional teaching, advocating to improve students' participation in the classroom has greatly mobilized students' autonomy and enthusiasm.

Teaching design of 5E Inquiry-Based Teaching

The core of the 5E inquiry-based teaching is the participatory teaching method of "emphasizing students' self-construction", which is the driving force of actively constructing concepts when new and old concepts conflict. Concept construction is an important part of the 5E inquiry-based teaching. Adopting the 5E inquiry-based teaching to carry out inquiry teaching will help stimulate students to put forward various problems worth exploring in life, and cultivate students' habit of finding reasonable research ideas and methods, that is, collecting evidence. Cultivate the thinking ability of analysis, interpretation and exercise.

Zheng Qiuhong and Gu Fengjuan (2011, pp.103-107) revealed that by analyzing the characteristics of the biology course and the disadvantages of traditional teaching, they introduced a new constructivist teaching model 5E inquiry-based teaching, changed the one-way transmission process of knowledge into the process of joint exploration between teachers and students under the guidance of teachers, mobilized students' enthusiasm and initiative to learn the course, and improved students' ability to solve experimental design, The 5E inquiry-based teaching plays an important role in cultivating "application-oriented talents with solid professional knowledge, strong application ability and high comprehensive quality"

Şen, Ş. and Erdoğan, Ü. I. (2016, p.58) pointed out that exploratory learning helps learners cultivate exploratory skills, which is one of the basic skills of the 21st century. Exploratory learning is defined as the process of learning through questioning and research, as well as the process of analyzing knowledge and transforming data into useful knowledge. Exploratory learning is a learning method based on constructivist theory, which is effective for students' learning and cultivating upper-level thinking abilities. In this method, students use the techniques used by scientists in scientific research to observe, collect evidence, speculate, conduct experiments, test possible explanations, and explain discoveries.

Sujarittham, T. Tanamatayarat, J. and Kittiravechote, A. (2019, pp.63-69) believes that the 5E inquiry-based learning cycle also can be tested for other social science subjects to examine another area of the learning outcome, such as students' critical thinking, communication skill, and so on. Improving students' basic biological skills is the main focus of biology teaching in middle schools at this stage, which plays a positive role in improving academic performance and developing students' various skills. Therefore, combining with the requirements of the new curriculum standard, it is of great research value to apply the 5E inquiry-based teaching in the teaching of high school biology. By analyzing the composition and connotation of 5E inquiry-based and its value in biology teaching in middle schools, this paper puts forward the strategy of applying 5E inquiry-based in biology teaching in high schools, and explains its application in practice with concrete cases.

Seçer, S. Y. E. and Yücel-Toy, B. (2020, pp.760-783) believed that the 5E inquiry-based learning is one of the models often mentioned in the constructivist approach. It identifies steps for teachers and students to deal with the curriculum in a cyclical form. It was proposed by Rodger Bybee in 1989.The 5E inquiry-based consists of activities that enhance students' curiosity to further study the topic, fulfill their expectations of the topic, and enable them to actively apply the knowledge and skills they have acquired. In this model, students are supposed to discover new concepts and combine them with their previous knowledge. When organizing educational activities, students can create their own knowledge as they are challenged. The 5E inquiry-based is the teacher's model of support and moderation.

This is the overall framework for the teacher.

Gao Lu (2021, pp.88-91) explored the use of the 5E inquiry-based teaching to guide students to understand and construct the concept of "transpiration of plants" on the basis of inquiry: create problem situations, let students expose their preconceptions, trigger cognitive conflicts, and "attract" students; Lead students to "explore" from macro phenomena to micro structures and enrich concepts; Let students express their understanding and "explain" the concept on the basis of inquiry; Guide students to summarize the conceptual significance through "transfer" application; Carry out "evaluation" to check students' mastery of concepts and skills.

Guo Rui (2022, p.64) believes that integrate the STSE education concept with the 5E inquiry-based teaching, and penetrate the STSE education concept into the biology class through all links of the 5E inquiry-based teaching, so that students can understand the relationship between biology and society and the important role of biology in environmental protection while mastering the basic terms and concepts, basic methods and principles of biology. The specific implementation process of the 5E inquiry-based teaching integrating the STSE education concept is proposed. The case design criteria and implementation principles of the 5E inquiry-based teaching integrating the STSE education concept are proposed, and the classroom teaching model of the 5E inquiry-based teaching integrating the STSE education concept is constructed.

On this basis, the 5E inquiry-based teaching can be used alone or in combination with other teaching methods. The 5E inquiry-based teaching enhances the interactivity of students' learning and obtains the learning experience of interactive discussion with peers. In traditional teaching, learners rarely have the opportunity to interact with others, while the 5E inquiry-based teaching focuses on students' hands-on operation, followed by interaction with peers, which just makes up for the lack of interaction between students and peers. Enhance the awareness and ability of autonomous learning. The 5E inquiry-based teaching enables students to discover, analyze and solve problems through their own exploration and communication with peers, and promote students' autonomous learning.

Practical application of 5E Inquiry-Based Teaching

As a new teaching mode with strong applicability, operability and good teaching effect, 5E inquiry-based teaching has attracted more and more scholars' attention in recent years and has been widely used in teaching of various disciplines.

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Seçer, S. Y. E. and Yücel-Toy, B. (2020, pp.760-783) believed that the 5E inquiry-based learning is one of the models often mentioned in the constructivist approach. The model identifies steps for teachers and students to process the lesson in a cyclical format. The model was proposed by Rodger Bybee in 1989.The 5E inquiry-based teaching consists of activities that enhance students' curiosity to further study the topic, fulfill their expectations of the topic, and enable them to actively apply the knowledge and skills they have acquired. In this model, students are supposed to discover new concepts and combine them with their previous knowledge. When organizing educational activities, students can create their own knowledge as they are challenged. The 5E inquiry-based teaching is the teacher's model of support and regulation. It is an overall framework for teachers.

He Zhi (2022, p.49) pointed out that in order to explore college basketball teaching, how to better grasp the key and difficult points of teaching content from the perspective of students, the 5E inquiry-based teaching was applied to college basketball girls' optional courses. The research showed that the students in the

experimental group and the control group improved in physical quality indicators after the teaching experiment, but there was no significant difference; After the teaching experiment, the students in the experimental group and the control group showed significant differences in basketball special scores (free throw line area shooting, half-court pass and catch, and basketball health knowledge); The 5E inquiry-based teaching has extremely significant effect on improving the female college students' interest in sports learning (negativity, skill learning, after-school activities).

Liang Yapeng (2022, p.`112) explores the 5E inquiry-based teaching, which focuses on exploration, pays attention to the subjectivity of students, and emphasizes the construction of concepts through exploration. Therefore, based on the educational concept of important concept teaching and inquiry teaching emphasized in the new curriculum standard and the characteristics of the inquiry teaching mode of 5E inquiry-based teaching, this study attempts to combine the 5E inquiry-based teaching with the important concept teaching of biology in senior high school. On the one hand, it provides a way to carry out the important concept teaching; on the other hand, it deepens students' understanding of important concepts and improves students' scientific inquiry ability through this inquiry teaching mode. Classroom observation scale designed with the dimension of "student learning" was used for classroom observation. The students in the experimental class performed better than the control class in breaking through the key and difficult points of teaching, understanding of important concepts, understanding and application of core knowledge and participation in activities.

Li Kaile (2022, pp.145-148) pointed out that in recent years, China has carried out a series of reforms in the field of education and revised the curriculum standards. The original monotonous teaching model has restricted the development of education in China to a certain extent. This restriction is particularly prominent in the teaching of biological experiments, which makes many students lose interest in biological experiments, which is not conducive to students' learning, but also indirectly affects the development of biological experiments. This requires teachers to actively explore new teaching models. Through the combination of 5E

inquiry-based teaching and the core literacy of the discipline, we carry out the practical research of biological experiment teaching, deeply explore the relationship between the core literacy of the discipline and the 5E inquiry-based teaching, design the biological experiment teaching scheme of the 5E inquiry-based teaching combining the core literacy of the discipline, further explore the specific implementation methods of the 5E inquiry-based teaching, and look forward to providing new ideas for improving the current situation of biological experiment teaching.

To sum up, from the above scholars' research, we can see that 5E inquiry-based teaching is an effective, efficient and effective teaching mode, which can promote students to actively participate in classroom learning, help students to enhance learning enthusiasm and improve teaching effect. Advanced abilities such as autonomous learning ability are also very effective.

Experimental Design Ability

The idea of "design of experiments" was first introduced in 1942 by the British statistician Felsch when he conducted experiments in the field. He believed that in order to demonstrate a natural phenomenon, we could adopt a series of procedural methods to design an experiment that would provide us with statistically significant results. The idea was first applied to experimental research in agriculture, then gradually applied to social science experiments, including educational experiments, and further refined and developed. In particular, the development of the SAPA (Science-A Process Approach) curriculum in the United States, which includes experimental design skills as part of the science process, has led to increased attention to experimental design ability.

The connotation of Experimental Design Ability

Experimental design ability refers to the ability to design experimental schemes, study biological phenomena and explore biological laws according to the requirements by using the measuring instruments, test methods and relevant knowledge learned. Different researchers have their own opinions in their own articles. There were important details as follows:

Ogilvie, C. A. (2009, p.48) classified scientific thinking abilities into high-level scientific thinking abilities and low-level scientific thinking abilities based on Bloom's classification. Analysis ability, evaluation ability, and innovation ability are important components of experimental design ability. They are interrelated and mutually reinforcing, and together they promote the success of experimental design. Therefore, in experimental design, it is necessary to comprehensively improve the analytical ability, evaluation ability and creative ability to achieve better experimental effect and value.

Dasgupta, A. P., Anderson, T. R. and Pelaez, N. (2014, pp.265-284) believed that the competencies required for a competent experimental design include identifying the problem; generating the hypothesis; planning the experimental procedure, including treatment, control, and outcome variables; and interpreting the study results to make inferences. These abilities can help researchers to design scientific and effective experiments so as to obtain accurate and valuable conclusions.

N L Choirunnisa, P Prabowo and S Suryanti. (2018, pp.261) believe that experiments are the best way to solve problems because they require consideration of scientific information from different sources. This information may come from literature reviews, professional knowledge and experience, results of previous studies, or opinions of other experts. Experimental design ability, as a type of experimental ability, is related to scientific processing ability and helps students understand and apply concepts to solve various problems.

Sujarittham, T., Tanamatayarat, J. and Kittiravechote, A. (2019, pp.63-89) pointed out that the ability to design experiments is a scientific ability to develop students' higher-order thinking skills for problem solving and the basic ability to operate the laboratory in a scientifically autonomous manner, as well as to prepare them for the future. It consists of five main elements: (1) linking physics concept, (2) defining measurement variables, (3) clarifying an experimental procedure, (4) selecting equipment and materials, and (5) minimizing errors.

He Yuyan (2019, p.38) pointed out in his emphasis on the cultivation of experimental design ability that experimental design ability refers to the innovative thinking and practical activities carried out by designing nuclear tests and flexibly

applying knowledge and skills under certain specific requirements and conditions. Experimental design ability can comprehensively cultivate students' ability to comprehensively use the knowledge they have learned, analyze and solve problems, express language and words, and unite and cooperate.

Du Zhongyong (2019, p.55) pointed out in the strategy of improving students' experimental design ability that experimental design refers to the planning of the whole process of the experiment, including putting forward questions, guessing hypotheses, designing experiments and customizing plans, conducting experiments and collecting evidence, analyzing and demonstrating, evaluating, communicating and cooperating, etc. The experimental design ability reflects whether students have the correct experimental instruments, scientific experimental processes, and rigorous experimental conclusions.

Shi Mei (2019, PP.150-151) pointed out in the training of senior high school chemistry experimental design ability that the so-called experimental design ability is the ability of students to use existing biological knowledge and experimental skills to conceive solutions to problems. Experimental design is an important element. It is a necessary condition for the realization of scientific inquiry and an effective way to cultivate students' innovative awareness and creativity.

Yang Shuxian (2020, PP.62-63) pointed out in the research on developing project-based learning to cultivate students' innovative experimental design ability that biological experimental design ability refers to the ability to design experimental schemes and investigation schemes to solve simple problems according to the known problems and conditions, and correctly select and use experimental equipment, determine or adjust experimental steps, and analyze experimental results by using the experimental methods learned. It has the characteristics of comprehensiveness, creativity and flexibility.

Zhang Xu (2022, p.87) reviewed the literature related to "experimental design ability" at home and abroad, sorted out the definition of experimental design ability, and combined with the 2017 edition of the General High School Biology Curriculum Standards, defined biological experimental design ability as the experimenter's ability to apply scientific knowledge and principles to the overall conception and planning

of an experiment based on the known information of the experiment given, before the hands-on operation. The experimental design ability is defined as the ability to apply scientific knowledge and principles to the overall conception and planning of an experiment, including the design of experimental methods, experimental hypotheses, experimental steps, and the expression of expected results, etc.

To sum up, as the most essential part of biological experiment ability, biological experiment design ability is a kind of innovative ability, with the core of cultivating and checking students' ability to collect and process biological information, analyzing and explaining experimental phenomena, as well as the thoughtful and clear-thinking habits and creative thinking.

Competency elements of Experimental Design Ability

Experimental design is a process of comprehensively applying learned knowledge and skills to conceive a solution to a problem. Experimental design ability is a higher level of experimental ability of important content which has the characteristics of strong synthesis, creativity and flexibility. Different scholars have different views on the understanding of the elements of experimental design ability.

Tang Yu (2023, p.36) believed that the process of experimental design involves analyzing experimental data, predicting experimental results and revising hypotheses. When predictions are consistent with experimental results, it only means that the hypothesis cannot be rejected. On the other hand, if the predictions are inconsistent with the experimental results, additional hypotheses need to be reconsidered or the hypotheses need to be modified or rejected.

Brownell, S. E. et al. (2014, pp.125-137) stated that experimental design is an essential competency for scientists, and that experimental design competency is a higher-order thinking that consists of 2 main elements (1) the ability to formulate a hypothesis and design an experiment to test that hypothesis (2) is to analyze data from simulated experiments and draw appropriate conclusions, and that the first element requires a level of synthesis, whereas the second element relies on the ability to analyze and evaluation abilities.

Sujarittham, T., Tanamatayarat, J. and Kittiravechote, A. (2019, pp.63-69) in his research suggests that a scientific competence is the "ability to design experiments",

which is a basic competence that helps students to solve problems in advanced thinking and scientific autonomy laboratory. The elements of students' experimental design competence are divided into the ability to connect physical concepts; the ability to define measurement variables; the ability to clarify experimental procedures; the ability to select equipment and materials; and the ability to minimize errors. In addition, there are a number of sub-competencies: the ability to measure basic physical quantities, the ability to use scientific equipment, and the ability to identify variables.

Zhang Xu (2022, pp.56-63) identified the elements of experimental design as four items: clarifying the purpose of the experiment, stating the relationship between variables, describing the experimental process, and the expected results of the experiment. In the study, it is pointed out that clarifying the purpose of experiment is a good start for experimental design, which requires students to be able to clearly formulate the problem and make assumptions; mastering the experimental principle is the scientific basis for experimental design, which requires students to be able to point out the independent variables, dependent variables and irrelevant variables and their corresponding relationships; controlling the relationship between variables is the core of the experimental design, which requires students to be able to effectively control the irrelevant variables and meet the Control of variables is the core of experimental design, students are required to be able to effectively control the irrelevant variables and comply with the principle of single variable, and at the same time be able to reasonably set up control experiments; the elaboration of the expected conclusions is the ultimate goal of experimental design, and students are required to express themselves in a scientific, standardized and logical manner.

Cheng, P. C. (2021, p.147) classified primary school science experiment design ability into five elements: (1) the ability to determine the goal of the experiment, which requires students to be able to clearly solve what a scientific problem or phenomenon. (2) The ability to determine experimental objectives requires students to know how to design an experimental programmed step by step. (3) The ability to organize information and select equipment requires students to be able to select suitable experimental materials and tools to carry out experiments, and to know

how to start thinking and consult relevant information. (4) The ability to design an experimental protocol requires students to consider what factors will affect the results of an experiment and to have a preliminary sense of controlling variables.

Xie Xiaoyan (2023, pp.221-224) subdivided the ability to design experiments in biology into seven competencies: (1) the ability to clarify the purpose of the experiment: this refers to the ability of students to use concise language to clarify the objectives of the experiment that should be achieved. (2) The ability to grasp the principles of the experiment: students are able to correctly state the relevant principles of the experiment. (3) Ability to predict results and explain phenomena: Students are able to predict possible experimental phenomena based on the experimental principles and explain the conclusions that the phenomena represent (or apply the experimental principles to explain the causes of different phenomena). (4) Ability to identify and control various variables: This refers to the ability to distinguish between the independent variable, the dependent variable, and various dependent variables affecting the results of the experiment, to set up a system to ensure the singularity of the variables, and to think of ways to eliminate the influence of extraneous variables on the results of the experiment. (5) The ability to select appropriate experimental materials and utensils: refers to the ability to select appropriate materials, reagents, medicines, etc., as well as observation tools, measurement tools, experimental instruments, etc., according to the needs of the experiment. (6) The ability to determine the data to be collected and the method of collection: according to the purpose of the experiment, determine the indicator data that can get the experimental results, and the method to be adopted for the collection of the indicator. (7) The ability to reasonably design experimental steps: write the already formed experimental ideas into logical and practical specific experimental steps, consider the problems that should be paid attention to in the experiment, and ensure the scientific and rigor of the operation.

To sum up, despite the differences in the specific descriptions of the elements of experimental design ability among researchers, they are all disassembled and described around the specific process of design in terms of content. Targeted cultivation of students' experimental design ability can stimulate students' interest in

science and cultivate their sense of cooperation, communication habits, practical ability, innovative spirit and other comprehensive qualities.

Strategies for cultivating of the Experiment Design Ability

Through the research, it is found that senior high school students' experiment design ability is not strong, and senior high school teaching must be adjusted accordingly to explore more effective training strategies to achieve the target requirements of the new curriculum standard for cultivating senior high school students' experiment design ability and promote the improvement of students' science literacy. The formation of experiment design ability should be based on mastering various relevant skills. Combined with the problems found in the survey, it is proposed to put forward feasible strategies for cultivating students' experiment design ability in senior high school teaching, aiming at strengthening the cultivation of this important ability.

Nina M. Goodey and Cigdem P. Talgar (2016, pp.34-35) argue that by allowing students to complete appropriate intellectual tasks in small groups, their grades, adherence to science courses, and attitudes towards science can all be improved. In addition, exploration is the core of scientific learning. In exploration, students describe objects and events, ask questions, construct explanations, test these explanations with current scientific knowledge, and communicate their ideas with others. Therefore, in the research, researchers redesigned our intermediate organic physiology experimental course, focusing on student designed plant and human physiology experiments to improve students' ability to design experiments and analyze data.

Brownel Brownell, S. E. et al. (2014, pp.125-137) pointed out that experimental design is an essential skill that is critical for success in science and for gaining fluency in scientific literacy and critical thinking. Guided by the idea that active learning methods are more effective than traditional lecture methods in improving student learning, the researcher designed two paper-and-pencil activities in the classroom: an analysis activity that required students to evaluate data; and a design activity that required students to propose a novel experiment. Although no significant difference was found between the two activities in terms of E-EDAT scores, both of which were

beneficial for improving students' experimental design ability, a 0.5-point difference between the design activity and the passive lecture was indeed observed. Students who completed the design activity but not the analysis activity performed significantly better on the Extended Experimental Design Ability Tool (E-EDAT) than students who participated in the experimental design teaching lecture.

Yue Suxia (2014, p.6) pointed out that we should attach importance to the experimental analysis of teaching materials, improve the ability to determine variables, make clear the problems and assumptions of the operation definition skills, and point out the direction for the experimental design activities. Next, we should start to design experiments. Any scientific experiment is to explore whether a factor is the cause of a phenomenon, and this factor has been put forward in the hypothesis as an independent variable. However, there are many factors that cause a certain phenomenon, and there are many variables, namely unrelated variables. Before designing the experiment, only accurately determine the variables, that is, identify the variables that affect the experiment, and distinguish independent variables, independent variables and dependent variables; And define the operation of each variable, that is, how to operate the independent variable, control the independent variable, and observe and measure the dependent variable; It has the premise of correct logical reasoning and can make the experimental design meaningful.

Sun Hu (2017, pp.106-107) believes that we should strengthen thinking training and design experiment ability. Design experiments require students to gradually locate the problems to be explored, turn the formed design ideas into concrete and operational implementation steps, and develop detailed experimental design plans. Designing experiments is the biggest feature of biological experimental design, and also the most difficult step in experimental design. Through the previous test, it was found that students' this skill was particularly weak, which became a key factor affecting the improvement of students' biological experiment design ability. The process of designing experiments is the process of scientific thinking. The quality of thinking is the core of the formation of design ability. Therefore, teachers should strengthen guidance, strengthen thinking training, and pay attention to the cultivation

of students' design ability. In the current senior high school biology textbook of the People's Education Edition, there is no special experimental design activity, and there is no special and systematic exposition of the basic principles and methods of biological experimental design. However, there are a lot of experimental design knowledge in the history of science and the experimental content of textbooks; In addition, there is a skill training column in the textbook, and targeted single skill training of design experiment is arranged. Therefore, teachers should make full use of the existing design experiment materials in the textbook, and start with the current situation and cultivation strategy of senior high school students' biological experiment design ability from three aspects: paying attention to the history of biological science teaching, using the exploratory experiment in the textbook, and paying attention to the technical training in the textbook, so as to train students' thinking and strengthen the design experiment ability.

Liu Zhuoyi (2018, pp.260) believes that hypothesis is a kind of scientific conjecture, which explains the causality and regularity between things or phenomena based on certain knowledge and experience, and answers the questions raised, providing direction for further collecting information and formulating experimental plans. The prediction results are based on the proposed assumptions and experimental principles, reasoning and judging the possible results of the experiment. If the predicted result appears in the experiment, the hypothesis is tenable; if the predicted result does not appear in the experiment, the hypothesis is not tenable. The prediction result is the result inferred from the hypothesis and also a reference for testing the hypothesis. Making assumptions and predicting results are the basis for designing experiments, and are indispensable and important links in experimental design.

He Xiaofang (2019, pp.175-176) believes that biological experiment design refers to the process of using existing knowledge and skills to design experiments to solve problems. The problem is the beginning of experimental design. Asking questions is an important skill that students should master. The skill of asking questions requires students to have strong problem awareness. The stronger the problem awareness, the more "why" and "what" are generated in the learning process, and the more active and active their thinking, the more conducive to the

emergence of problems. Therefore, in teaching, teachers' pay attention to creating problem situations, cultivating students' problem awareness, and teaching students some methods to make students good at raising questions. Traditional teaching attaches importance to the cultivation of students' problem-solving ability. Students are often used to solving established problems rather than asking questions themselves. If students are to find and explore independently, it is difficult for them to put forward questions worthy of study on related matters. Therefore, stimulating students' awareness of raising questions is the premise of cultivating students' awareness of raising questions. In teaching, we should give students the opportunity to ask questions, let them find the contradictions through phenomenon observation and material analysis, and then ask questions, instead of teaching materials or teachers arranging students to design experiments around what problems.

Farley, E. R., Fringer, V. and Wainman, J. W. (2020, pp.350-356) believed that traditional general chemistry laboratory courses often lack the opportunity for students to design their own experiments, opting instead to provide students with predetermined protocols. Such laboratory exercises are often referred to as "cookbook" laboratory exercises, which require students to follow a detailed step-by-step protocol. While these exercises can be effective in exposing students to a wide range of basic laboratory skills; however, a curriculum consisting entirely of cookbook-style experiences does not provide students with the opportunity to evaluate laboratory techniques, design and plan experimental protocols, and solve problems in their designs. In order for students to have the opportunity to practice experimental design skills, the researchers will exercise their experimental design ability through open-ended laboratory exercises and propose a method to transform the traditional "cookbook" laboratory course into a more open-ended course that includes developing clear learning objectives, assessing the existing curriculum for consistency with these objectives, and providing opportunities to incorporate experimental design into the course. and providing opportunities to incorporate experimental design, as well as modifying existing protocols. The new course will increase students' confidence in their experimental design ability and their ability to experiment compared to students in traditional courses.

Zhang Xu (2022, pp.167-171) proposed to strengthen the training of biological experimental design problems and improve students' ability to solve experimental design problems. The survey shows that with the increase of grade, students' biological experiment design ability and various skills level also gradually improve. This shows that with the growth of age and the enrichment of knowledge and experience, practice can promote the improvement of students' ability. Many studies also show that the improvement of the design ability of biological experiments is not a result of stimulation, but a gradual process that requires repeated understanding and practice. Ericsson and others found that an important factor affecting the development of experts' ability is intentional practice by focusing on "the development of experts' ability in the field of their expertise". There is a close relationship between the formation of capacity and activities. Capacity is formed and developed in activities and plays a stable role in regulating the process and mode of activities. After students have the basic quality of experimental design, they must also express it in standard written form. Through practice, students can train their thinking logic and written expression ability. It can be seen that strengthening exercise training plays an important role in improving students' biological experiment design ability.

To sum up, experiment design is an important way to stimulate students' interest in biology, improve students' scientific inquiry ability, and comprehensively improve students' biological scientific literacy. In recent years, with the comprehensive development of basic education reform and the deepening of the new curriculum reform and college entrance examination reform, experimental design has received more and more attention. How to effectively improve students' ability of biological experiment design has become the subject and important content of biological teaching.

Evaluation method of Experiment Design Ability

Experimental design ability is an indispensable component of scientific inquiry ability, and it is also an important component of the ability goals in the "High School Biology Curriculum Standards (Experiments)". A credible survey tool was selected to investigate and analyze the current situation of senior high school students' biological experimental design ability and their mastery of various skills that affect their

biological experimental design ability, and based on this, feasible cultivation strategies were proposed to further improve the cultivation methods of biological experimental design ability in theory. Different researchers used different evaluation methods for experimental design ability.

Sirum Karen and Humburg Jennifer (2011, pp.8-16) argue that the goals of higher education include helping students develop evidence-based reasoning skills; Therefore, it is important to understand the scientific thinking skills required for basic experimental design. The Experimental Design Ability Test (EDAT) measures students' understanding of good experimental design standards by answering open-ended questions based on daily life science questions. Using a direct scoring standard to analyze students' reactions, EDAT provides a consistent and rapid assessment. Managing electronic data testing only requires minimal student and classroom time, and it can measure benefits in the form of pretest/posttest. It is worth noting that EDAT is independent of content and terminology, with the lowest requirement for quantitative skills. Our research results indicate that EDAT is sensitive to the improvement of experimental design ability, as in our sample, only students who participated in the redesigned introductory biology course showed significant improvement in experimental design ability, including clear guidance and experience in using scientific methods.

Dasgupta, A. P., Anderson, T. R. and Pelaez, N (2014, pp.265-284) developed the well-validated Biological Experimental Design Concept Inventory (BEDCI), consisting of 14 items in 8 categories, to assess this biological experimental design competency. Researchers have demonstrated in their studies that the BEDCI is a reliable and valid diagnostic tool that measures non-majors' thinking about experimental design. The BEDCI is sensitive in detecting differences between groups of students and in measuring individual and group shifts in student learning.

Zhang Yan (2014, pp.97-99) pointed out that applying the evaluation method of work order to experimental design ability requires students to systematically record their thinking process of experimental design on the work order. Different from the traditional test, it not only focuses on the results of the experimental design, but also on a series of ability elements presented in the experimental design.

In one activity, it can evaluate students' experimental design ability more truly and effectively. Work order evaluation is an effective method to evaluate the ability of experimental design, which is widely recognized by the international scientific and educational circles at present.

Li Qiong (2017, pp.182-187) pointed out in a survey of senior high school students' biological experimental design abilities that test survey methods, questionnaire survey methods, and interview methods are mainly used to evaluate experimental design abilities. Based on the requirements for students' experimental abilities in the high school curriculum standards and the college entrance examination syllabus, self-compiled "Questionnaire on the Status Quo of High School Students' Biological Experimental Learning" was conducted for science students in the third grade of our school, mainly to understand the attitude of high school students towards biological experiments, the ability to use instruments, select reagents, clarify the experimental process, and process data The ability to express experimental results and innovate in experiments. Through interviews with students, we can understand their opinions and opinions on experimental teaching in our school. The test survey method is mainly based on the requirements for students' experimental design ability in the college entrance examination syllabus. Referring to past college entrance examination questions and local simulation questions, the diagnostic test question for students' experimental design ability, "High School Students' Biological Experimental Design Ability Test Question," is compiled. Three different levels of science classes (Class A, Class B, and Class C) are selected from our school based on their scores for testing and comparison, to understand students' experimental design abilities.

Farley, E. R., Fringer, V. and Wainman, J. W. (2018, pp.350-356) believed that designing experiments and applying the scientific process are core competencies that biology students develop in their undergraduate education, and that experimental design includes a range of scientific process skills such as hypothesis generation, data collection decisions, and data analysis. All components of experimental design are interrelated, and internal consistency among the components is critical. Because of the interconnectedness and complexity of the experimental design components,

authentic assessment is particularly important for assessing students' ability to design experiments. The investigators designed a checklist instrument to examine undergraduate biology students' experimental design abilities in the context of an introductory laboratory course, and successfully assessed the experimental design abilities of introductory undergraduate biology students by scoring and analyzing all participants' responses using the TIED. In particular, the structured, open-ended response format of the assessment revealed students' thought processes and reasoning on key components of experimental design.

Zhang Junpeng et al. (2022, pp. 50-59) pointed out that the PTA scale can be used as a practical evaluation tool to evaluate students' behavior in a multi-dimensional and multi-level way. The PTA scale divides students' different performance into different grades according to the scoring criteria. It first divides a certain behavior of students into several basic elements, and has a standard scoring basis for each basic element. These basic elements are evaluated separately, and then the evaluation of each element is summarized to evaluate the overall behavior of students. This evaluation method truly and objectively reflects the learning situation of students, and can be targeted to improve the problems of students. It conforms to the educational concept of "students as the main body".

Yu Ruolan (2022, pp.145-149) pointed out in his research that questionnaire, interview, and testing methods were used to evaluate experimental design ability. In the testing method, real problem situations are given, and genetic experimental design questions are divided into four types: explicit and recessive trait judgment, genotype judgment, gene location judgment, and situational information judgment. The tester is asked to complete the genetic experimental design independently, and evaluate the experimental ideas, expected results, and conclusions written by him. To understand the changes in students' ability to design genetic experiments before and after the implementation of teaching strategies through two tests.

To sum up, it can be seen from the studies of the above researchers that the evaluation methods of experimental design ability mainly include interview method, questionnaire method, test paper method, scale method and worksheet method. Although there are various ways of evaluation, the basic method is to decompose the

process of experimental design, the description of each process after decomposition, and then scoring, and the quantitative scoring method is respected for its intuitive advantages.

Middle school course

In today's world, with rapid economic and social changes and advances in science and technology, it is necessary to adapt the provisions of basic education, which must be harmonized with such changes and advances. Innovative strategies must be identified to improve the quality of education, which necessarily responds to the needs of individuals and societies, as well as to the ability of learners to compete and cooperate creatively in the world community.

Middle School Curriculum (Ministry of Education of the People's Republic of China,2020)

Ordinary middle school education is a basic education aimed at the entire population, which further improves the national quality on the basis of compulsory education. The mission of regular middle school education is to promote the comprehensive and personalized development of students, prepare them for their social life, higher education, and career development, and lay the foundation for their lifelong development. The curriculum construction of ordinary middle schools adheres to the Party's educational policy, implements the fundamental task of establishing morality and career, develops quality education, promotes educational fairness, strives to build a dynamic Chinese characteristic curriculum system that reflects international development trends, and cultivates socialist builders and successors with comprehensive moral, intellectual, physical, and aesthetic development.

1. Cultivation Objectives

On the basis of compulsory education, the general middle curriculum further enhances the comprehensive quality of students and focuses on the development of students' core qualities, so as to enable students to have ideals, beliefs and a sense of social responsibility, scientific and cultural literacy and lifelong learning ability, as well as the ability to develop independently and the ability to communicate and cooperate.

2. Curriculum development

2.1 Academic structure and hours of study

The duration of general middle school is three years. Each school year consists of 52 weeks, including 40 weeks of teaching time, 1 week of social practice, and 11 weeks of vacation (including summer and winter vacations, holidays, and farm vacations). There are 35 class hours per week, and each class hour is 45 minutes long. 18 class hours are worth one credit.

2.2 Types of courses

The GSS curriculum consists of three types of courses: compulsory, optional compulsory and elective. The compulsory and optional compulsory courses are the national curriculum, and the optional courses are school-based. Compulsory courses are set by the state in accordance with the needs of students' all-round development and must be taken by all students. The optional compulsory courses are set by the state according to the needs of students' individual development and the needs of the entrance examination for higher education. Students participating in the national unified examination for admission to colleges and universities must choose relevant subjects within the scope of this type of course; other students, in combination with their interests and hobbies, must also choose to study part of the subject content in order to meet the requirements for graduation credits. Elective courses are developed and set up by schools in accordance with the diversified needs of students, the needs of local social, economic and cultural development, the recommendations of subject curriculum standards, and the characteristics of the school's operation, etc., and are taken by students on their own initiative.

2.3 Subjects and credits offered

General middle schools offer national courses in language, mathematics, foreign languages, ideology and politics, history, geography, physics, chemistry, biology, technology (including information technology and general technology), art (or music and fine arts), physical education and health subjects, and comprehensive practical activities and labor, as well as school-based courses. The specific credit arrangements are as follows:

Table 2.3 Schedule of Credits for General Middle School Courses

subject	Compulsory credits	Optional Required Credits	elective credits
multilingualism	8	0～6	0～6
Mathletics	8	0～6	0～6
foreign languages	6	0～8	0～6
ideology and politics	6	0～6	0～4
histories	4	0～6	0～4
geographically	4	0～6	0～4
physiotherapy	6	0～6	0～4
chemotherapy	4	0～6	0～4
Biology	4	0～6	0～4
Technology (including information technology and general technology)	6	0～18	0～4
Art (or music)	6	0～18	0～4
Sports and Health	12	0～18	0～4
Integrated Practical Activities	8		
labor	6		
add up the total	88	≥42	≥14

Note: School-based courses are not less than 14 credits. Of which, not less than 8 credits shall be courses other than subject expansion and enhancement courses designed on the basis of compulsory and optional compulsory courses.

2.4 Organization of subjects

Subject content is designed according to the characteristics of the subject itself and the learning needs of students. Compulsory content is in principle designed by semester or academic year, while optional compulsory and elective content is in principle designed by module. Modules are relatively independent of each other and reflect the internal logic of the subject. The teaching time of the modules is set according to actual needs and is generally a multiple of 18 hours.

Foreign languages include English, Japanese, Russian, German, French and Spanish. Schools choose the first foreign language independently. Schools are encouraged to create conditions for offering a second foreign language. Technology includes Information Technology and General Technology, the compulsory contents of which are designed as modules of 3 credits each. Art can be substituted with Music and Fine Arts, and the specific subjects to be offered are determined by the schools themselves. The compulsory content of Physical Education and Health must be offered continuously throughout the three years of senior secondary education. A total of 8 credits of integrated practical activities, including research studies, party activities, military training, social visits, etc. 6 credits of research studies (completion of 2 topics of research or project design, with a focus on conducting interdisciplinary research). A total of 6 credits for labor, including 2 credits for volunteer service, conducted outside the classroom, and no less than 40 class hours for three years. The content of the remaining 4 credits is coordinated with the elective and compulsory content of general technology and the content of school-based courses.

2.5 Graduation credit requirements

Students who complete the required hours of study and pass the examination (test) for the corresponding course will be awarded the corresponding credits. The minimum number of credits required for graduation is 144 credits. Among them, 88 credits are compulsory courses, 42 credits are optional compulsory courses and 14 credits are elective courses.

Middle School Biology (Ministry of Education of the People's Republic of China,2020)

1. Nature of the course

Biology is a basic discipline in natural science, a science that studies the phenomena of life and the laws of life activities. It is the basis of agricultural science, medical science, environmental science and other related sciences and technologies. The study of biology has gone through a development process from phenomenon to essence and from qualitative to quantitative. Nowadays, it is developing very rapidly in both micro and macro directions, and is having an increasing impact on society, economy and human life through its increasingly close integration with information technology and engineering technology. The senior secondary biology curriculum is one of the important subject courses in the field of science, and is a continuation and expansion of the relevant courses at the compulsory education level. Its essence is to demonstrate the basic contents of biology and reflect the nature of natural science. It aims to enable students to acquire basic biological knowledge as well as to realize the viewpoints held by biologists in the process of research as well as the ideas and methods of problem solving. The biology curriculum requires students to take the initiative to participate in learning, to acquire biological knowledge in the process of asking questions, obtaining information, searching for evidence, testing hypotheses, and discovering laws, to develop the habit of scientific thinking, to form a positive attitude toward science, and to develop lifelong learning and creative and practical abilities. Learning biology is an indispensable educational experience for every citizen, and its learning outcomes are the basic components of civic literacy. This course is a disciplinary course aiming at improving students' core qualities in biology, and it is an important carrier for establishing socialist core values and realizing the fundamental task of cultivating morality and educating people.

2. Disciplinary core literacy and curriculum objectives

2.1Academic core literacy

Core literacy of a discipline is the centralized expression of the value of disciplinary education, which is the correct values, necessary character and key abilities that students gradually develop through disciplinary learning. The core literacy of the discipline of biology includes the concept of life, scientific thinking, scientific inquiry and social responsibility.

2.2 Course Objectives

Through the study of this course, students will be able to realize the important contribution of biology in insisting on the harmonious coexistence of human beings and nature. Through the study of this course, students can recognize the important contribution of biology in insisting on the harmonious coexistence of human beings and nature, promoting the development of science and technology, social progress and improving the quality of human life; establish the concepts of life, and be able to use these concepts to understand the phenomena of life and to explore the laws of life; form the habit of scientific thinking, and be able to use the existing knowledge of biology, evidence and logic to think about or argue about the biological issues; grasp the idea and method of scientific investigation, form the spirit of cooperation, and be good at exploring or trying to solve real-life problems at the practical level; have the willingness to carry out practical activities in biology and social responsibility in facing the challenges of the real world. They have the willingness to carry out practical activities in biology and a sense of social responsibility; when facing the challenges of the real world, they can make full use of their biological knowledge to take the initiative in publicizing and guiding, and they are willing to take the social responsibility of boycotting drugs and bad habits, so as to lay the foundation of understanding and practice for further study and going into the society.

3. Course structure

3.1 Structure

The middle school biology curriculum is divided into three parts: compulsory, selective compulsory and elective. The compulsory part includes two modules: "Molecules and Cells" and "Heredity and Evolution"; the optional compulsory part includes three modules: "Homeostasis and Regulation", "Biology and Environment" and "Biotechnology and Engineering"; and the elective part involves real-life applications, career planning and academic studies. The optional compulsory part consists of three modules, namely "Homeostasis and Regulation", "Biology and Environment" and "Biotechnology and Engineering"; the elective part involves a number of extension modules in three directions, namely, real-life application, career planning and foundation for academic development.

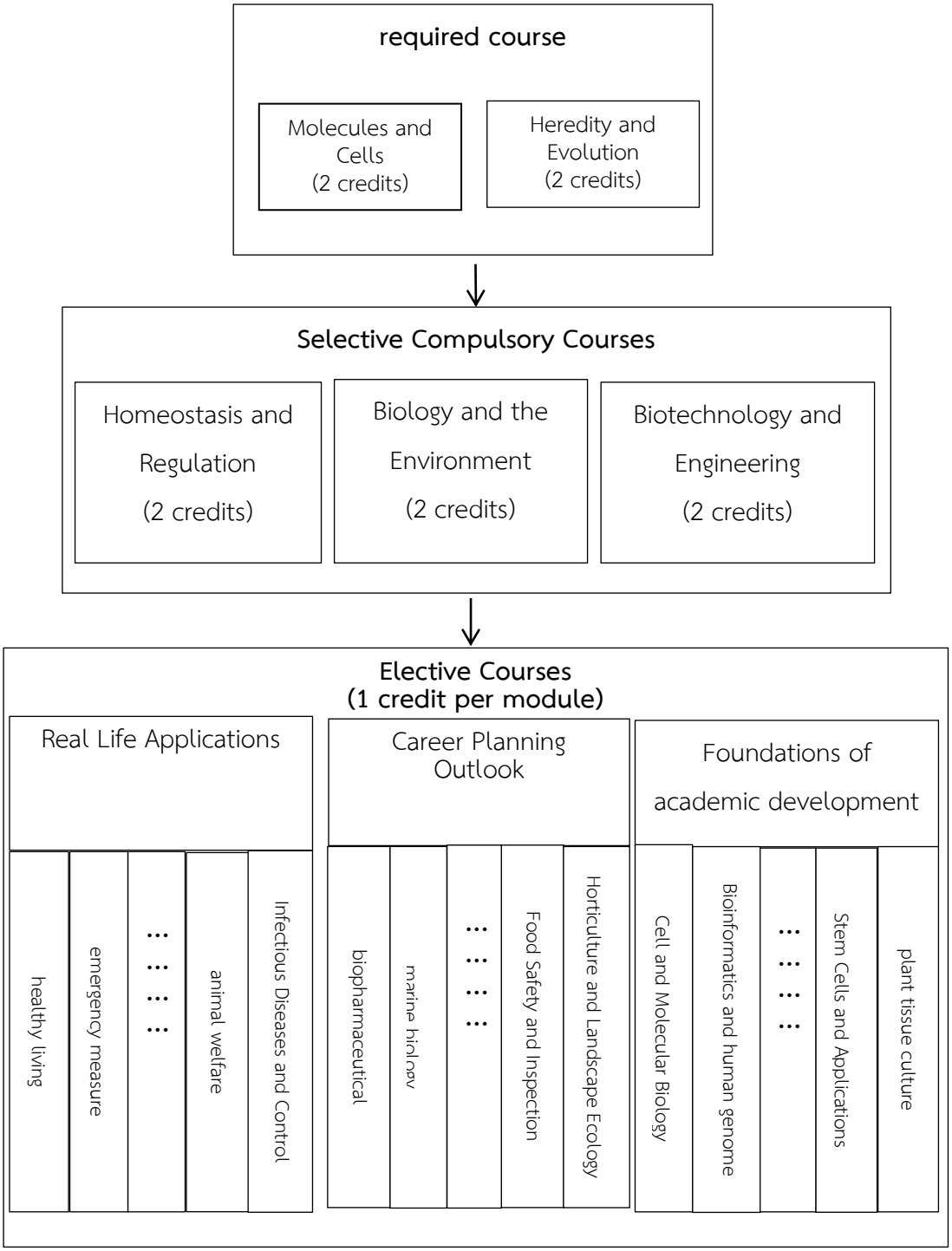

Figure 2.2 High School Biology Curriculum Structure

Source: General high school curriculum standards. China. Ministry of Education

3.2 Credits and course selection

The total number of compulsory credits for this course is 4, with each compulsory module being 2 credits and each credit requiring 18 hours of teaching. Each credit requires 18 credit hours of instruction. Each student must complete 2 compulsory modules, totaling 72 hours, 2-4 hours per week, it is recommended to be offered in the first year of middle school.

On the basis of completing the compulsory credits of the program, students may take optional compulsory and elective courses according to their interests and aspirations. Students can take optional compulsory and elective courses according to their interests and aspirations on the basis of completing the compulsory credits of the program. Each module of the optional compulsory courses is worth 2 credits, and each module of the elective courses is worth 1 credit. Each module of the optional compulsory courses is worth 2 credits and each module of the elective courses is worth 1 credit, and each credit requires 18 hours of teaching. After completing the compulsory courses, students can directly study the selective compulsory or elective courses, or they can no longer take the courses in their discipline. courses in this discipline. Students who choose biology to be included in the total admission score of college admission should complete all modules of the elective compulsory courses. Selective compulsory and elective courses can be offered at the same time for students to choose. Teachers may propose the order or conditions for the selection of the modules of the elective courses under the category of "Fundamentals of Academic Development". For modules in the "Fundamentals of Academic Development" category of the elective courses, teachers may propose the order or conditions of selection. Students may take no more than 4 credits of courses from the elective modules. Students may take no more than 4 credits of courses from the elective modules.

4. Course content

The required courses are the core content of modern biology and play an integral role in improving the core literacy of all students in the discipline of biology. Compulsory courses are the foundation for learning selective compulsory and elective courses. The compulsory courses are oriented to all middle school students

and select the most basic and important concepts of biology. In order to enable students to better understand and master the content, teaching should attach great importance to the practical aspects of students, and strive to provide students with more opportunities for hands-on practice. After completing the required courses, students can directly study selective required or elective courses, or they can no longer take courses in this discipline. Students who choose Biology to be included in the overall results of college admissions should complete the all modules of the elective compulsory courses. The elective courses are designed to help students to better prepare for life and employment, as well as to meet the needs of some students who choose to pursue scientific research.

5. Teaching suggestions

The fundamental task of the Biology Curriculum is to improve the core literacy in the discipline of Biology needed for students' lifelong development. To accomplish such a teaching task, teachers need to pay attention to every student in the teaching process, to the learning process in every lesson, and to strive to promote students' good development on the basis of the original foundation. For this reason, the Ministry of Education has put forward seven suggestions about biology teaching in high schools. (1) Paying great attention to the achievement of core literacy in biology (2) organizing active learning characterized by inquiry is the key to the implementation of core literacy in biology (3) helping students to form the concept of life through the learning of big concepts (4) strengthening and perfecting the experimental teaching of biology (5) implementing the education on the interrelationships of science, technology and society (6) paying attention to the connection between disciplines (7) focusing on the history of biological science and the learning of the nature of science.

6. Evaluation recommendations

Evaluation is an indispensable and important part of the daily teaching process, and is an important means for teachers to understand the teaching process, regulate the behavior of teaching and learning, and improve the quality of teaching. Evaluation is student development-oriented, based on the content of the biology curriculum and academic quality standards, focusing on the core qualities of the

discipline, and promoting teachers' teaching and students' learning.

6.1 Evaluation principles

The evaluation should follow the guiding ideology of establishing morality and emphasizing the formation of students' patriotism and social responsibility; the evaluation should pay attention to students' understanding and integration of the major concepts of biology; the evaluation should point to the development of students' core literacy in the discipline of biology; the evaluation should embody orientation and incentives; and the evaluation methods should be diversified. So that the evaluation not only promotes the improvement of students' core literacy level, but also promotes the improvement of teachers' teaching level, and realizes the purpose of common development of the evaluator and the evaluated.

6.2 Content of the evaluation

The evaluation content should be based on the curriculum objectives, course content and academic quality standards, combined with specific teaching content, and based on the main concepts of biology, important concepts and other main knowledge, to detect the level of development of students' core literacy in the discipline of biology. The evaluation mainly includes the following contents.

1) Students' concept of life

2) The development of students' scientific thinking

3) Students' ability of scientific inquiry

4) Students' sense of social responsibility.

6.3 Evaluation approach

Evaluation should be based on the different evaluation contents and targets, and adopt diversified evaluation methods. The choice of evaluation methods should take into account the actual situation of evaluation objectives, evaluation content, evaluation targets and evaluation sites, and may take the form of a combination of students' self-assessment and mutual assessment, group assessment and teacher assessment.

6.4 Feedback on results

Scientific analysis of evaluation results and timely feedback are

conducive to improving the timeliness of evaluation. Teachers should make reasonable explanations of the evaluation results according to the teaching purposes and with reference to the relevant standards. Timely feedback on students' learning can be provided in the form of comments and conversations. Attention should be paid to discovering and developing students' potential, stimulating students' enthusiasm and initiative in learning, and promoting the development of students' core literacy in the discipline of biology.

7. Academic level examinations

Academic level examinations include the qualifying examination for middle school graduation and the graded examination for middle school graduation, the main purpose of which is to evaluate the development of students' disciplinary core literacy. The academic level qualifying examination for middle school graduation is to examine the achievement of the core literacy of all students in the discipline of biology, and its content is based on the requirements of the compulsory curriculum, with the difficulty not exceeding the requirements of the second level of academic quality. The difficulty of the test questions in the academic level qualifying examination for middle school graduation shall be lower than that in the academic level grading examination, so that students who persist in normal study can generally meet the requirements of the qualifying level that middle school graduates should meet. The content scope of the Academic Level Graded Examination is based on the requirements of compulsory and optional compulsory courses, and the difficulty does not exceed the requirements of the Academic Quality Level 4; under the premise of strengthening the fundamentals, it highlights the students' subject specialties and embodies the function of screening and selection.

Relevant research

5E Inquiry-Based Teaching

5E inquiry-based teaching is a new teaching model that takes cooperative inquiry learning as the organizational form of classroom teaching. This teaching model mainly stimulates students' interest in learning, cultivates students' ability of cooperative inquiry and problem solving, encourages students to build new skills and

knowledge system independently, and can apply new skills and knowledge in new situations.

D'Acunto, I. et al. (2018, pp.275-278) applied the 5E inquiry-based teaching to improve the scientific skills of primary school students. They believed that the main objective of this study is to describe the effectiveness of 5E instructional model-based learning to improve primary school students' science process skills. The science process skills are important for students as it is the foundation for enhancing the mastery of concepts and thinking skills needed in the 21st century. The design of this study was experimental involving one group pre-test and post-test design. The result of this study shows that (1) the implementation of learning in both of classes, IVA and IVB, show that the percentage of learning implementation increased which indicates a better quality of learning and (2) the percentage of students' science process skills test results on the aspects of observing, formulating hypotheses, determining variable, interpreting data and communicating increased as well.

Turan, S. and Matteson, S. M. (2021, pp.22-39) applied the 5E inquiry-based teaching to the practice of high school mathematics classrooms, and they pointed out that the 5E inquiry-based teaching is famous for increasing students' investment and participation in the learning process. When watching videos of high school mathematics teachers' courses, researchers noticed that teachers find it difficult to faithfully implement the 5E inquiry-based teaching. This case study explores the degree to which mathematics teachers use the 5E inquiry-based teaching in the classroom by analyzing video courses. The survey results indicate that the challenges faced by teachers vary. They find it difficult to find activities related to the stage, shifting from a teacher centered approach to a student-centered approach, which is considered a challenge for teachers. The findings of this study inform educators of the difficulties faced by teachers in faithfully implementing the 5E inquiry-based teaching. In addition, the researchers also elaborated on the specific stages that teachers need to address when engaging in professional development in classroom teaching.

Zhang Yuming (2021, pp.178-184) integrated STEM education and applied the

5E inquiry-based teaching to junior high school physics teaching. He pointed out that since 2015, the State Council and the Ministry of Education have issued several policy documents and pointed out that the STEM education model should be further explored and developed in primary and secondary school education. In the new curriculum standard of junior high school physics, it was proposed that students' interdisciplinary knowledge integration ability, practical inquiry ability, independent thinking ability, etc. should be enhanced; the above abilities are advocated and developed by STEM education philosophy. However, through field research, it is found that the current primary and secondary schools do not pay enough attention to STEM education and lack of education and professional courses on STEM ability. Through the analysis of the survey data, we can find that the current situation of physics teaching in junior high school has the following problems: teachers are not accurate in their own positioning, ignoring the cultivation of students' awareness of inquiry; Too much emphasis on the examination of textbook knowledge and lack of the use of experimental methods to construct knowledge; It pays too much attention to basic knowledge and ignores the cultivation of students' creative thinking. Therefore, it is necessary to integrate and design the teaching model, endow each step of STEM education meaning in the five-link teaching of "introduction - exploration - interpretation - transfer - evaluation", and realize the process of "introduction - collective construction - individual construction - transfer - internalization" of STEM knowledge. In each round of inquiry activities, students' personalized and diversified learning effects promote the horizontal and vertical development of their own cognitive thinking. Through the construction and processing of knowledge, it not only deepens the connotation and extension of knowledge itself, but also deepens the generation and transfer of knowledge.

Zhang Zhu (2021, pp.234-239) applied the 5E inquiry-based teaching to the research of geography teaching design. He pointed out that with the issuance of the latest version of the General High School Geography Curriculum Standard China's reform in geography curriculum has entered a new stage. The curriculum standard clearly puts forward the four core qualities of geography: the concept of human-earth coordination, comprehensive thinking, regional cognition and geographical practice,

and emphasizes the innovative learning methods of cultivating students' core qualities of geography through cooperation and exploration. 5E inquiry-based teaching, as a teaching model in line with the trend of education development, has been effectively verified. It is emphasized that starting from the five links of "introduction, inquiry, interpretation, transfer and evaluation", we should create a real geography classroom, let students explore problems independently, and build a knowledge framework. Therefore, studying the combination of the two in the classroom has certain research significance.

Peng Cong (2021, pp.54-57) applied the 5E inquiry-based teaching to the inquiry of high school chemistry. He believed that inquiry learning was the main learning method of students. 5E inquiry-based teaching is the main mode to guide students' inquiry learning. When organizing high school chemistry teaching activities, based on students' subjectivity and according to the requirements of inquiry teaching in the curriculum standard, the author applies the 5E inquiry-based teaching to guide students to explore. In the research, the author will elaborate on creating situations and introducing new knowledge in combination with teaching experience; Propose tasks and explore new knowledge; Cooperate and exchange, explain new knowledge; Present problems and use new knowledge; Multiple interactions, evaluation of these teaching strategies of new knowledge, provide teaching reference for other front-line chemistry teachers.

Liu Zhenling (2022, pp.167-174) took junior high school basketball teaching as an example, designed teaching plans based on 5E inquiry-based teaching, formulated teaching tasks and implementation methods according to 5E inquiry-based teaching, implemented teaching plans, and achieved teaching effects through teaching practice. Through research, he believes that 5E inquiry-based teaching is an effective teaching mode, which can not only stimulate students' autonomous learning ability, but also improve the efficiency of teachers and students in solving problems in limited classroom time to a certain extent, and can be widely used in basketball teaching. The implementation of 5E inquiry-based teaching in junior high school basketball teaching can better help students master basketball technical actions and basketball theoretical knowledge, and can also more effectively promote sports learning interest.

Li Han (2022, pp.236-243) applied the 5E inquiry-based teaching to scientific inquiry in primary schools. She believed that citizens' scientific literacy affects national competitiveness, and its level is closely related to science education; In recent years, in science education and teaching in primary schools in China, problems such as the weakening of students' experience, the fragmentation of the process of inquiry, and the simplification of evaluation methods are more prominent; Accelerating the innovation of science education model has become the key to the high-quality development of science education. The 5E inquiry-based teaching, based on constructivism, plays an important role in highlighting students' subjectivity, promoting the structural and hierarchical process of inquiry, constructing discipline concepts, and promoting the diversification of evaluation methods. In the study, from the five dimensions of inquiry consciousness, inquiry ability, inquiry process, inquiry effect and inquiry evaluation, the author analyzed five problems of scientific inquiry learning in primary schools, such as insufficient understanding of inquiry learning, too fixed inquiry process, not prominent student's main position, lack of cultivation of construction and application ability of subject concepts, and outdated evaluation methods; The reasons for the problems are analyzed from the following aspects: teachers' insufficient application ability of inquiry learning, students' weak awareness of inquiry and unbalanced development of inquiry ability, schools' insufficient attention to inquiry learning and imperfect external support system. This paper expounds the effectiveness of 5E inquiry-based teaching applied to scientific inquiry learning in primary schools from three aspects: conforming to the curriculum design concept, conforming to the characteristics of primary school students' scientific cognitive development, and reflecting the construction essence of learning, and expounds its feasibility from three aspects: the same teaching essence, the same teaching process, and the same teaching characteristics.

Boakye, S. and Nabie, M. J. (2022, pp.14-35) aims to investigate the impact of online 5E inquiry-based teaching on the curriculum performance, attitude, and retention of sixth grade music courses in high school. This study has a pre-test and post-test control group, which is one of the semi experimental models. According to the research purpose, the subjects are 40 students from a private middle school in Türkiye. Compare the scores of achievement tests, attitude tests, and retention tests among each group

using the Mann Whitney U test. There is a significant difference in the music post class test and attitude scores between the experimental group using the constructivist 5E inquiry-based teaching for online teaching and the control group using traditional teaching methods for online teaching.

Ge Wei (2023, pp.51-54) applied the 5E inquiry-based teaching to the teaching of administrative law courses. He pointed out that the 5E inquiry-based teaching consists of five links: introduction, exploration, interpretation, transfer and evaluation. It is student-centered and attaches importance to the independent construction of relevant knowledge and content by students. The current administrative law course teaching is still a face-to-face mode, with teachers and students trapped in the classroom, limited to class hours, limited to textbooks, unable to effectively meet the needs of the training objectives of outstanding legal talents, deviated from the national standards of law teaching quality in colleges and universities, and deviated from constructivist teaching ideas and paradigms. Teachers can apply the 5E inquiry-based teaching to the teaching of administrative law courses. The introduction link can be achieved in a variety of ways, the exploration link can be open and inclusive, the interpretation link can avoid a single stereotype, the transfer link can prevent mechanical solidification, and the evaluation link should strive to be organic and diverse.

Experimental Design Ability

With the continuous deepening of education reform, the new curriculum standard clearly puts forward the basic idea and curriculum goal of physics curriculum in the compulsory education stage to cultivate students' innovation ability, cultivate students' inquiry ability, and improve students' ability to find and solve problems. In the process of scientific inquiry, the element of designing experiment is one of the important links that relate to the success of the inquiry and link the past and the future.

Yu Ruolan (2022, pp.146-154) applied experimental design ability to genetics for high school students. She pointed out that based on the core competencies proposed in the new high school biology curriculum standard, cultivating high school students' genetic experimental design ability to promote the improvement of students' scientific exploration ability and the development of scientific thinking. This

study applies the hypothesis deduction method to the classroom of cultivating the ability to design genetic experiments in high school biology. Through teaching practice, the ability to design genetic experiments for high school students has been improved. At the same time, teaching cases of genetic experiment design ability are provided, hoping to provide reference and basis for frontline teachers' teaching.

Liu Zhenling (2022, pp.256-162) applied experimental design ability to high school physics teaching. He pointed out that the Chinese high school physics curriculum standards clearly state that students should understand the importance of experimental design in experiments. The 2017 version of the high school physics curriculum standards divided the level of experimental design ability in the "Academic Level Requirements" column. Through literature research, it has been found that many researchers have pointed out that students' level of experimental design ability is not high, or even low; Although many teachers and scholars have studied how to cultivate and evaluate students' experimental design ability, there are many differences in the structural elements of experimental design ability proposed by everyone; Although the curriculum standard divides the level of experimental design ability, it is only a general description and does not provide specific elements of experimental design ability. The important prerequisite for cultivating and evaluating students' experimental design ability is to know the structure and elements of experimental design ability, and only then can targeted cultivation and evaluation be carried out.

Zhou Xiaomin (2022, pp. 276-284) applied experimental design ability to high school chemistry virtual experiment teaching. She pointed out that chemical experimental design ability is a kind of ability for students to solve practical chemical problems based on existing knowledge and experience. In 2018, various parts of the new high school chemistry curriculum standards issued by China required students' experimental design ability. Therefore, the cultivation of chemical experimental design ability has become an indispensable part of chemistry teachers' experimental teaching. The current research on cultivating students' experimental design ability mainly focuses on teacher guidance. However, as a student's ability to solve practical problems on their own, using appropriate methods and means can completely

enable students to independently design solutions to practical chemical problems.

Zhang Luwen (2022, pp.178-186) applied experimental design ability to high school physics teaching. He pointed out that experiments are an important way of scientific exploration, and experimental design ability is a necessary key ability in experimental exploration. Based on the international experimental ability evaluation standards, three evaluation elements and seven specific indicators of exploratory experimental design ability in high school physics were determined. The level of experimental design ability was divided using SOLO classification theory as guidance, a framework for evaluating the design ability of high school physics exploratory experiments has been constructed, and a situational paper and pencil testing tool has been developed using the framework. This has implications for the teaching and evaluation of high school physics exploratory experiments.

Tang Yu (2023, pp.198-204) applied experimental design ability to the learning of science among middle and senior primary school students. She pointed out that with the continuous emphasis of science education on students' core competencies in exploratory practice, the cultivation of scientific experimental design ability, as a basic element of scientific inquiry ability cultivation, is increasingly being valued by nature teachers in primary and secondary schools. The author attempts to understand the situation of teachers in cultivating students' scientific experimental design ability in daily teaching from three dimensions: their understanding, attitude, and strategy towards cultivating students' scientific experimental design ability. This study has positive significance for enriching the design theory of cultivating experimental design ability and improving the current situation of cultivating experimental design ability.

To sum up, through the analysis of the relevant literature of the 5E inquiry-based teaching, it is found that the teaching model has strong practicability in different disciplines and has great advantages in improving students' learning enthusiasm and experimental design ability. When different scholars use the model on a large scale in teaching, they will continue to try to optimize the details to better adapt to different types of courses and knowledge requirements. At the same time, according to the actual content of different courses, more and more scholars

began to try to innovate the application form of 5E inquiry-based teaching according to different teaching theories and concepts to help students improve their experimental design ability and learning effect to a higher degree.

Chapter 3

Research Methodology

Using 5E inquiry-based teaching to improve the experimental design ability for middle school students. The research using experimental research methodology have the following procedures.

1. The population /the sample Group
2. Research Instruments
3. Data Collection
4. Data Analysis

The population / Sample Group

The Population

There are 120 students in the first year at Weifang Beichen Middle School, divided into 4 classes with 30 students in each class.

The Sample Group

Through cluster random sampling, 30 students from Class 2, Grade 1 with mix abilities (strong, medium, and weak) in Weifang Beichen Middle School.

Research Instruments

Using 5E inquiry-based teaching to improve the experimental design ability for middle school students. The research Instruments is as follows:

1. Lesson plan according to the 5E inquiry-based teaching
2. Experimental design ability assessment

The details were as follows:

Lesson plan according to the 5E Inquiry-Based Teaching:

The purpose of lesson plans was to improve the experimental design ability by applying the 5E inquiry-based teaching that teaches in biology courses. This experiment is divided into the following four learning units:

1. learning unit 1: Structure and function of cell membrane (3 hours)

2. learning unit 2: Active transportation and endocytosis, exocytosis (3 hours)

3. learning unit 3: Enzymes that reduce the activation energy of chemical reactions (3 hours)

4. learning unit 4: Photosynthesis and energy conversion (3 hours)

The development process of creating Lesson plan according to the 5E inquiry-based teaching and assessment form for validity of lesson plan were followed as.

1. Studying the principles of creating Lesson plan according to the 5E inquiry-based teaching and assessment form for validity of lesson plan from books, textbooks, articles, and related research.

2. Creating a Lesson plan according to the 5E inquiry-based teaching and assessment form for validity of lesson plan, 4 plans as this above.

3. Drafting the assessment form for validity of lesson plan at the end of each section, there was a space for experts to write suggestions that could be helpful in improving students 'experimental design ability.

4. Taking the instruments to 3 experts to verify the validity. The assessment consistency the index of congruency was between 0.67-1.00, the level of consideration is as follows:

Rating is +1. There is an opinion that "Corresponds to definition/measurement objectives."

Rating is 0. There is an opinion that "Not sure it corresponds to definition/ measurement objectives."

Rating is -1. There is an opinion that "Inconsistent with definition/ measurement objectives."

5. Modifying assessment form for validity of lesson plan according to suggestion.

6. Taking the research instruments to collect data with the research samples.

Experimental Design Ability Assessment:

The development process of creating the assessment of experimental design ability and assessment form for validity of the assessment of experimental design ability were followed as.

1. Studying the principles of the assessment of experimental design ability and

assessment form for validity of the assessment of experimental design ability from books, textbooks, articles, and related research.

2. Creating an experimental design ability assessment and assessment form for validity of experimental design ability assessment.

The experimental design ability assessment consisted of four competencies that proposed by Zhang Xu (2020) are a comprehensive and reasonable division of students' experimental design ability, which is classified into the following:

1) Specify the purpose of an experiment ability

2) State the relationship of variables ability

3) Describe the experimental procedure ability

4) Express the expected results of an experiment ability

Referring to scholars Zhang Xu (2020) and Xie Xiaoyan (2023) observation and evaluation criteria for the development of students' experimental design ability, and design the evaluation assessment scale on this basis.

3. Taking the instruments to 3 experts to verify the content validity and index of items objective congruence (IOC) of the assessment form. The assessment consistency the index of congruency was between 0.67-1.00.

4. Modifying assessment form for validity of lesson plan according to suggestion.

5. Taking research instrument to test reliability and the result of reliability was 0.96.

6. Taking the research instruments to collect data with the research samples.

Table 3.1 Experimental Design Ability Scoring Criteria

Evaluation Items	Score and criterion 3	2	1
specify the purpose of an experiment ability	Able to give reasons for the questions and hypotheses that have been asked, and the reasons are scientifically sound	Although reasons can be given for the questions and hypotheses that have been asked, the reasons are not scientifically sound enough	Although questions and hypotheses can be asked, they are not well reasoned
state the relationship of variables ability	Able to name all the variables and indicate the relationship of change, follows the single variable principle, and can satisfy the purpose of the experiment	Able to name some of the variables and point out the relationship of change, following the principle of a single variable, and basically fulfilling the purpose of the experiment	Able to name all the variables but unable to point out the relationship of change, although following the principle of a single variable, it does not fulfil the purpose of the experiment

Table 3.1 Experimental Design Ability Scoring Criteria (continue)

Evaluation Items	Score and criterion 3	2	1
describe the experimental procedure ability	Able to write down developed experimental ideas into logical, practical and specific experimental steps, as well as being able to consider what to look for in an experiment so as to ensure that the operation is scientifically sound and rigorous.	Able to write down developed experimental ideas into logical, practical and specific experimental steps, but unable to consider comprehensively the problems that should be noted in the experiment, and the operation lacks scientific and ragout.	The process of writing the formed experimental ideas into experimental steps lacks a certain logic and practicality, fails to comprehensively consider the problems that should be paid attention to in the experiment, and the operation lacks scientific and ragout.

Table 3.1 Experimental Design Ability Scoring Criteria (continue)

Evaluation Items	Score and criterion 3	2	1
express the expected results of an experiment ability	Able to accurately predict possible experimental phenomena and explain the conclusions indicated by these phenomena, or apply experimental principles to explain the causes of different phenomena.	Able to accurately predict experimental phenomena that may occur, but unable to clearly explain the conclusions indicated by these phenomena, or apply experimental principles to explain the causes of different phenomena.	While predicting possible experimental phenomena, they are not sufficiently accurate, nor are they able to clearly explain the conclusions indicated by these phenomena, or to apply experimental principles to explain the causes of different phenomena.

Evaluate quality standards

Score Range	Quality Level
23-24	Strong
19-22	Relatively strong
15-18	General
11-14	Relatively weak
8-10	Weak

Data Collection

In this research, the data collection period is used for the first semester of the 2023 academic year from August 30, 2023 to September 8, 2023, total of 12 hours. Follow the steps as follows.

1. This research is experimental research. One Group Pretest – Posttest. Design was used with the following experimental design:

Table 3.2 Experimental Design

Group	Pretest	Experimental	Posttest
E	T_1	X	T_2

The meaning of the symbols used in the experimental design.

E means Random Sampling

X means experimental

T_1 means Pretest

T_2 means Posttest

2. Taking the assessment of experimental design ability to obtained from the analysis, the difficulty value, Discriminant power, and reliability value. Then it was assessment before class with the students that were research samples

3. Teaching according to lesson Plans that using 5E inquiry-based teaching to improve experimental design ability. Organized teaching by the researcher about 6 hours per week, total 12 hours.

4. After completing the teaching, Teacher conducted with using the same assessment of experimental design ability to students. The scores obtained from the assessment were recorded to compare the experimental design ability of students before and after learning.

5. Getting data obtained from teaching activities according to using 5E inquiry-based teaching to analyze the data according to statistical methods.

Table 3.3 The lesson plans specific teaching time

No.	Date	Time	learning unit
Lesson 1	August 30st 08:30-11:40	3 hours	Structure and function of cell membrane
Lesson 2	September 1th 08:00-11:10	3 hours	Active transportation and endocytosis, exocytosis
Lesson 3	September 6th 08:00-11:10	3 hours	Enzymes that reduce the activation energy of chemical reactions
Lesson 4	September 8th 08:00-11:10	3 hours	Photosynthesis and energy conversion

Data Analysis

The data analyzed as follows:

1. Quantitative data were analyzed through descriptive statistics; means, and standard deviation.

2. Quantitative data were analyzed through inferential statistics; Then calculate the different score of experimental design ability before and after using 5E inquiry-based teaching were analyzed through t –test for dependent samples.

Chapter 4

Results of Analysis

The objective of this study is to using 5E inquiry-based teaching to improve the experimental design ability for middle school students and to and compare the experimental design ability of students before and after the implementation of the 5E inquiry-based teaching. The data analysis results are as follows:

1. Symbol and abbreviations
2. Results of data analysis

The details are as follows.

Symbol and Abbreviations

Represent data analysis results based on symbols and semantics. The details are as follows:

n	means the number of students
$\bar{x}$	means the average
SD.	means the standard deviation
D	means the difference in scores between before and after learning
df	means degree of freedom
t	means the statistical value to be used in the t-test
**	means statistical significance at level .01

Results of Data Analysis

1. Results of using 5E Inquiry-Based Teaching to improve the Experimental Design Ability

5E inquiry-based teaching is a teaching model based on cognitive psychology and constructivist learning theory proposed by the United States curriculum reform, and is a way of promoting students' cognitive learning in science courses based on inquiry combined with the "learning loop" teaching method. It emphasizes student-centered problem solving through the use of investigation and experimentation,

and promotes students' understanding of scientific concepts and knowledge construction through cooperative group learning. Researchers have conducted many literature studies on 5E inquiry-based teaching: Bybee et al. (2006); Bybee (2014); Wu (2022); Senl and Oskay (2017), etc., and all of them believe that 5E inquiry-based Teaching includes five phases, namely Engagement, Exploration, Explanation, Elaboration, and Evaluation. In this study, the researcher also categorized the development of lesson plans into five steps based on the 5E inquiry-based teaching steps: 1) Engagement 2) Exploration 3) Explanation 4) Elaboration 5) Evaluation. Three experts were invited to evaluate the quality of the lesson plans using 5E inquiry-based teaching and they agreed that the lesson plans were very suitable for teaching.

This study was conducted on 30 middle school students from Weifang Beichen Middle School, with the objective to improve the experimental design ability of middle school students using the 5E inquiry-based teaching. The detailed results of the experimental design ability scores before and after the application of the 5E inquiry-based teaching in biology courses are shown in Table 4.1

Table 4.1 Experimental Design Ability score between before and after learning

Experimental Design Ability	n	Full Scores	Pre-test		Post-test		D
			$\overline{X}$	SD.	$\overline{X}$	SD.	
1. specify the purpose of an experiment ability	30	6	4.10	1.18	5.03	1.10	0.93
2. state the relationship of variables ability	30	6	4.03	1.35	4.83	1.32	0.80
3. describe the experimental procedure ability	30	6	4.17	1.32	4.73	1.23	0.56

Table 4.1 Experimental Design Ability score between before and after learning (continue)

Experimental Design Ability	n	Full Scores	Pre-test $\overline{X}$	Pre-test SD.	Post-test $\overline{X}$	Post-test SD.	D
4. express the expected results of an experiment ability	30	6	3.73	1.20	4.67	1.00	0.94
total		27	16.03		19.27		3.24

From Table 4.1, it can be seen that changes in the four sub-competencies of the experimental design competencies of middle school students using 5E inquiry-based instruction:1) the ability to clarify the purpose of the experiment : the average score before learning was 4.10, and the average score after learning was 5.03, with an average difference of 0.93; 2) the ability to explain the relationship of variables : the average score before learning was 4.03, and the average score after learning was 4.83, with an average difference of 0.80; 3) the ability to describe the experimental process : the average score before learning was 4.17 points before learning and 4.73 points after learning, with an average difference of 0.56 points; 4) the ability to express the expected results of the experiment: the average score before learning was 3.73 points, and the average score after learning was 4.67 points, with an average difference of 0.94 points, and the scores of all the items after learning were higher than those before learning. Therefore, using 5E inquiry-based teaching can improve junior high school students' experimental design ability and achieve the research objectives.

2. Results of Comparison of Experimental Design Ability of Middle School Students before and after adopting 5E Inquiry-Based Teaching

Researchers used pre and post learning experimental design ability scores to analyze the data using mean statistics, standard deviation, and t-tests. The results of the data analysis are shown in Table 4.2

Table 4.2 the comparison of Experimental Design Ability score between before and after learning

Experimental Design Ability		n	Full Point	$\bar{X}$	SD.	t	p
Total score	Pre-test	30	24	16.03	3.89	11.13	0.00
	Post-test	30	24	19.27	3.08		**

**Statistically significant at level .01 (p <.01)

Table 4.2 shows that the mean scores of the first-year students' experimental design ability after the class were higher than the mean scores before the class, indicating that the students' experimental design ability after the class was higher than before the class. p<.01 indicates statistical significance at the .01 level. By implementing 5E inquiry-based instruction to the students, their experimental design ability was significantly higher after class than before class. This is consistent with the research hypothesis.

3. Learning Behavior

The researchers used the 5E inquiry-based teaching to improve the experimental design ability of middle school students. In order to validate the findings, the researcher observed the students' behavior during the teaching and learning process. In this study, when the 5E inquiry-based teaching was used to teach 30 first-year high school students in Beichen Middle School in Weifang in the biology course, the students' behaviors were observed and recorded in the five teaching sessions of Engagement, Exploration, Explanation, Elaboration, and Evaluation in each class. Changes in students' behaviors indicated a gradual improvement in their experimental design ability throughout the learning process. Students' learning behaviors during the schedule of instructional activities were recorded as follows:

Step 1: Engagement

At this stage, the teacher attracts students by creating problematic situations connected with real life, causing cognitive conflicts among students, thus stimulating students' interest in active exploration and active construction of knowledge. The teaching results show that in the first class, only 6 students were able to actively

participate in analyzing and completing the questions posed by the teacher, while the completion rate of the other students was less than 50%, which indicates that the students were not active in participating in the course activities and were unable to take the initiative to carry out inquiry activities. In the last class, 29 students were able to actively participate in analyzing and completing the questions posed by the teacher, indicating that the majority of students showed great interest in learning.

Step 2: Exploration

In this stage, the teacher guides the students to conduct an inquiry based on the cognitive conflicts generated in the previous session. In the process of inquiry, students were able to be guided to think about the purpose of the experiment and observe the experimental steps carefully. The teaching results show that in the first class, only five students were able to answer the teacher's questions accurately, clarify the purpose of the course experiment, and have a good grasp of the steps of the experiment, while the other students needed to be guided by the teacher in order to basically complete the teacher's tasks. In the last class, 27 students were able to answer the teacher's questions in the classroom well after careful thinking, indicating that the students' ability to clarify the purpose of the experiment and to describe the experimental process has been improved.

Step 3: Explanation

At this stage, the teacher will give students the opportunity to demonstrate their understanding of the knowledge, mastery of the skills or application of the methods, and allow them to try to explain their understanding of the knowledge in their own words. Teaching results show that in the first class, about 90% of the students were not clear about the conceptual orientation of the independent and dependent variables that appeared in the experimental process, and only three students were able to elaborate on the changes in the relationship between the independent variable and the dependent variable; five students were able to predict and explain possible experimental phenomena, and the majority of the students were inconsistent in the scientific nature of the linguistic expression of the expected results of the experiments with the logical inconsistency of the experimental design before and after the experimental process. In the last class, 28 students could

correctly make judgments about the various variables in the experimental process, and 27 of them also predicted and analyzed the experimental results basically correctly, which showed that the students grew in their ability to identify and elaborate the relationship between variables and their ability to express the expected results of the experiment.

Step 4: Elaboration

At this stage, under the guidance of the teacher, students continue to deepen their understanding and application of knowledge, expand the basic meaning of knowledge, and apply new knowledge to explain new situations or problems. Through hands-on practice, students can deepen or expand their understanding of knowledge and acquire additional information and skills. In the class, students were asked to complete a complete experimental design based on the lab materials and utensils provided by the instructor. In the first class, only six students completed the tes assessment t in the allotted time. In the final class, all 29 students completed the assessment independently within the allotted time, and one student eventually completed the assessment with the help of a classmate as well.

Step 5: Evaluation

At this stage, teachers use formal or informal methods to assess students' understanding and application of new knowledge. Teachers provide targeted instruction on the completion of experimental design questions and evaluate the quality of their completion in the form of scores, as well as subjective quantification of the students' overall performance. In the first class, only two students got more than 20 points on the assessment, and most of the students could not accurately grasp the factors that should be considered in the experimental design of biology and their sequence, could not integrate the parts of the experimental design process well, and lacked an overall grasp of the experimental program. In the last class, 16 students got more than 20 points in the assessment, and more than 80% of the students could determine the purpose of the experiment and formulate a reasonable experimental plan based on the experimental materials and paraphernalia provided by the teacher, including the experimental methodology, steps, and the prediction and expression of the experimental results.

To sum up, the experiment of using 4 lesson plans according to the concept of 5E inquiry-based teaching, the researcher found that 5E inquiry-based teaching is a very effective teaching mode in improving the experimental design ability of secondary school students. Through the five phases of 5E inquiry-based teaching, it not only allows students to master scientific knowledge in inquiry, but also allows students to improve their experimental design ability while conducting scientific inquiry. After the implementation based on 5E inquiry-based teaching, the students 'experimental design ability has been improved obviously as specified by the research hypothesis.

Chapter 5

Conclusion Discussion and Recommendations

Using 5E inquiry-based teaching to improve experimental design ability for middle school students was experimental research that has the research objective as follows:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

The samples Group are 30 students from Class 2, Grade 1 with mix abilities (strong, medium, and weak) of high school in Weifang Beichen Middle School, China. Through the cluster random sampling method, in the first semester of the academic year 2023.

The research instruments were used in this study which were 4 lesson plans based on the 5E inquiry-based teaching and experimental design ability assessment.

Conclusion

According to the research topic, the study on improving the experimental design ability of middle school students through 5E inquiry-based teaching is summarized as follows:

1. By using 5E inquiry-based teaching and observing students' learning behaviors, it is found that students have improved in clarifying the purpose of the experiment, explaining the relationship of variables, describing the experimental process, express the expected results of the experiment, and the ability of experimental design.

2. Comparing of experimental design ability of students before and after learning with the 5E inquiry-based teaching, it was found that after learning was higher than before learning by statistically significant at the .01 level. This was consistent with the research hypothesis.

Discussion

Research on using 5E inquiry-based teaching to improve experimental design ability for middle school students was research that could develop experimental design ability in 30 first-year students from Beichen Middle School in Weifang City, using the 5E inquiry-based teaching in the first semester of the 2023 academic year, can be discussed as follows:

1. Using the 5E inquiry-based teaching to improve students' experimental design ability. Researchers have studied many relevant literature and research on Inquiry Based teaching, and have summarized it into five steps for developing lesson plans based on the 5E inquiry-based teaching of middle school students. Data analysis involves three experts evaluating the quality of lesson plans based on exploratory teaching methods, and the results are presented by experts on the quality of lesson plans. Overall, the suitability of research objectives is the most appropriate. This is because the developed learning plan is consistent with the concept of 5E inquiry-based teaching, and the developed curriculum plan includes key elements of the curriculum plan. Learn complete and relevant content clearly and comprehensively. The established activities emphasize the practical learning, practical thinking, and practical abilities of learners in experimental design. In terms of measurement and evaluation, it is determined to be an assessment based on actual situations, measured according to learning objectives, and determined whether the workpiece and workload are suitable based on learning objectives, which is consistent with the research of Qiu (2022) and Zhang (2022) .They pointed out that combining the 5E inquiry-based teaching with the requirements of practical activities in the teaching process in the basic concept of the new curriculum standard; we should carry out practical research on the biological activity class, and explore the relevance between the activity class and the 5E inquiry-based teaching . The students' core literacy level has been greatly improved through the learning in the high school biological activity class under the 5E inquiry-based teaching. The results of student self-evaluation and mutual evaluation show that students' interest in biology learning is significantly improved through the learning of biological activity class under the 5E inquiry-based teaching. Through practical

teaching case studies of the 5E inquiry-based teaching, the full application of the 5E inquiry-based teaching in practical teaching has achieved student learning results. In addition, Singh (2020) emphasized that exploratory learning is another criterion for effective knowledge transfer. She serrated out that although people might expect different things/practices when they referred to inquiry-based learning, there were decisive Characteristics that required being nearby, including an integrated prospectus across regulation, a problem-based teaching room, and deliberation to skills enlargement. The research results of Xinjing (2022) indicate that the 5E inquiry-based teaching reflects students' subjectivity in the teaching process. The teaching process of exploratory teaching method generally includes five steps. With the continuous development of the new curriculum reform, the theoretical and practical research of the teaching model has also shown a trend of prosperity. In order to meet the requirements of the new era for talent cultivation, the inquiry teaching model advocating active independent learning, cooperative learning and inquiry learning has been placed in an important position. There is further elaboration on the development and implementation of 5E inquiry-based teaching in different literature.

2. Comparison of students' experimental design abilities before and after learning using 5E inquiry-based teaching. The results showed that the average score before learning was 16.03 points, and the average score after learning was 19.27 points, with an average difference of 3.24 points. The results showed that the experimental design ability of 30 students after learning was higher than that before learning, with statistical significance at the 0.01 level, which is consistent with the hypothesis. 5E inquiry-based teaching lies in its student-centered approach, which stimulates students' interest through practical experimental design skills, enhances each student's participation, and promotes the development of their comprehensive abilities. This is consistent with Du (2019), He pointed out in the strategy of improving students' experimental design ability that experimental design refers to the planning of the whole process of the experiment, including putting forward questions, guessing hypotheses, designing experiments and customizing plans, conducting experiments and collecting evidence, analyzing and demonstrating, evaluating,

communicating and cooperating, etc. The 5E inquiry-based teaching emphasizes that learning activities are long-term, autonomous, student-centered, and integrated with real-world problems and practices. The 5E inquiry-based teaching is a teaching method that focuses on students' independent exploration, which helps to cultivate students' experimental design ability to the maximum extent possible. Through the 5E inquiry-based teaching, students' experimental design ability has been significantly improved. The results indicate that the 5E inquiry-based teaching has a positive impact on students' success, and selecting teaching methods that are suitable for students' personal interests and abilities is very important.

Recommendations

General recommendation

1. The 5E inquiry-based teaching may consume more time than other teaching methods; therefore, teaching design needs to be done well in the process of 5E inquiry-based teaching.

2. Teachers should strengthen guidance for students or groups, as the Inquiry Based teaching model usually focuses on self-directed exploration in learning methods; In some cases, it is difficult to identify the key and difficult points of teaching, which can weaken the students' learning willingness and interest. Therefore, teachers should strengthen scientific guidance for students, so that they can correctly grasp how to effectively explore independently.

3. Teachers should create a good classroom learning atmosphere while organizing classroom activities. Encourage students to express themselves and dare to express their opinions. The passion for learning is what makes learning management successful.

4. Achievement exhibitions can be set up to showcase excellent projects, in order to promote and encourage other students, increase their interest and participation.

Suggestions for further research

1. In this study, only 5E inquiry-based teaching was used to improve students' experimental design ability, and other teaching methods or teaching modes can be further considered to improve students' experimental design ability, or a combination of teaching methods or teaching modes can be combined to improve students' experimental design ability, such as: flipped classroom, group cooperative learning, PBL teaching method, etc.

2. This study improved students' experimental design ability through 5E inquiry-based teaching, and it has been verified to be effective, but students' abilities are also multi-faceted, so we can consider using 5E inquiry-based teaching to improve students' abilities in other areas, such as critical thinking ability, problem solving ability, innovative thinking ability, etc., which will help students' comprehensive ability development.

3. This study uses the secondary school biology curriculum as a vehicle to use 5E inquiry-based teaching to improve students' experimental design ability, and can consider applying the 5E inquiry-based teaching method to other secondary school curricula, or even to a wider range of disciplines, so as to develop a unique teaching style.

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Appendixes

Appendix A

List of Specialists and Letters of Specialists Invitation for IOC Verification

Appendix A
List of Specialists and Letters of Specialists Invitation for IOC Verification

Name of Experts	Position/Office
1.Associate Professor Dr. Jittawisut Wimuttipanya	Ph.D. Curriculum and Instruction Bansomdejchaopraya Rajabhat University
2.Assistant Professor Sarawut Samanya	Master of Public Administration Bansomdejchaopraya Rajabhat University
3.Professor Dr. Dong Shousheng	Ph.D. in Education East China Normal University

Appendix B

Official Letter

Ref.No. MHESI 0643.14/883

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

18 August 2023

RE Invitation to validate research instrument

Dear Associate Professor Dr.Jittawisut Wimuttipanya

Miss Yin Hua is a graduate student in Master of Education Program in Curriculum and Instruction of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Using 5E Inquiry Based Teaching to Improve Experimental Design Ability for Middle School Students"

The thesis adversity committee has considered that you are an expert in this topic. Your recommendations would be useful for further improvement of this research instrument.

We respectfully request your assistance in validating a research instrument that is attached to this message. We would be grateful for any help you can provide in this matter. We would like to express our sincere appreciation for your time and expertise. If you have any questions or concerns, please do not hesitate to contact Miss Yin Hua at 591449493@qq.com

Thank you for considering our request.

Sincerely,

Nainapas I

(Dr.Nainapas Injoungjirakit)
Vice Dean, For Dean of the Graduate School

Bansomdejchaopraya Rajabhat University
Tel.+662-473-7000 ext. 1814
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Ref.No. MHESI 0643.14/884

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

18 August 2023

RE. Invitation to validate research instrument

Dear Assistant Professor Dr.Sarawut Samanya

Miss Yin Hua is a graduate student in Master of Education Program in Curriculum and Instruction of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Using 5E Inquiry Based Teaching to Improve Experimental Design Ability for Middle School Students"

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Sincerely,

Nainapas I.

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Vice Dean, For Dean of the Graduate School

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Ref.No. MHESI 0643.14/885

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

18 August 2023

RE: Invitation to validate research instrument

Dear Professor Dr.Dong Shousheng

Miss Yin Hua is a graduate student in Master of Education Program in Curriculum and Instruction of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Using 5E Inquiry Based Teaching to Improve Experimental Design Ability for Middle School Students"

The thesis adversity committee has considered that you are an expert in this topic. Your recommendations would be useful for further improvement of this research instrument.

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Thank you for considering our request.

Sincerely,

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Appendix C

Research Instruments

Lesson Plan I

The first semester of the first year of high school

Department	Weifang Beichen Middle School Biology Teaching and Research Department
Course name	Biology (Compulsory I): Structure and function of cell membrane
Target Audience	Senior High School Year 1, Class 2
Number of students	30
Teaching Time	3 hours
Lecturer	Yin Hua

Content

Structure and function of cell membrane

Objective of Leaning

1. The student can identify the purpose of an experiment about the structure and function of cell membranes

2. The student can state the relationships of variables in an experiment on the structure and function of cell membranes.

3. The student can describe the process of an experiment on the structure and function of cell membranes.

4. The student can express expected outcomes of experiments on the structure and function of cell membranes.

Main point/concept

Structure and function of cell membrane

Cell membranes are mainly elastic, semi-permeable membranes composed of phospholipids, 7-8 nm thick, and for animal cells, the outer side of the

membrane is in contact with the external environment. Its main functions are selective exchange of substances, absorption of nutrients, excretion of metabolic wastes, and secretion and transport of proteins. The components of cell membrane include phospholipids, glycoproteins, glycolipids and proteins; according to the composition structure, phospholipid bilayer is the basic scaffold of cell membrane. The main components of cell membranes are proteins and lipids, with small amounts of sugars. Some of the lipids combine with sugars to form glycolipids, and some of the proteins combine with sugars to form glycoproteins; chemically, the cell membrane is mainly composed of lipids (mainly phospholipids), proteins and sugars; among them, proteins and lipids are predominant. Under the electron microscope, it can be divided into three layers, i.e., an electron-dense band of about 2.5 nm thick on each side of the membrane, and a transparent band of 2.5 nm thick in the middle, with a total thickness of about 7.0-7.5 nm. This structure is not only seen in various cell membranes, but also in various organelle membranes such as mitochondria and endoplasmic reticulum, whi have similar structures.

Cell membranes have important physiological functions, both in maintaining the intracellular environment for stable metabolism and in regulating and selecting substances to and from the cell. The cell membrane absorbs, digests and expels substances outside and inside the cell membrane through pinocytosis, phagocytosis or exocytosis. The plasma membrane also plays an important role in cellular recognition, signaling, cellulose synthesis and microfibril assembly. Some intercellular information exchange does not rely on receptors on the cell membrane, such as sterols secreted by some cells, which can act as signals to communicate with other cells, but these substances do not bind to receptors on the cell membrane, but cross the cell membrane and bind to certain receptors in the nucleus or cytoplasm, thus mediating information exchange between two cells.

Learning Activity

The teacher explains to the students the purpose and manner in which the experimental design ability assessment will be administered and distributes the assessment questions prior to conducting the formal lesson and asks the students to

complete the assessment in 1 hour.

Project-based learning activities have 5 stages as follows: 1) Engagement stage, 2) Exploration stage, 3) Explanation stage, 4) Elaboration stage, and 5) Evaluation stage.

1. Engagement stage

This link is the starting link of the 5E inquiry-based teaching. In order to attract students' interest in learning tasks and stimulate students to explore actively, the 5E inquiry-based teaching generally emphasizes the creation of problem situations to stimulate students' interest in learning. The problem situation here should be connected with the real life (especially the students' life) as much as possible, and with the course content and teaching tasks. Problems in the situation can attract students and cause cognitive conflicts, thus stimulating students' interest in actively exploring and actively constructing knowledge

1.1 In the form of a game, draw students' attention, stimulate their interest and make them get into the state as soon as possible:

The teacher takes a balloon and fills it with enough water, then sticks the balloon with a needle.

Ask: (1) What is the division between the water balloon and the outside world? (2) What happens when you stick the water balloon with a needle (3) What can you say about the boundaries of the system have what kind of function? The boundary of a balloon is similar to which structure in a cell?

1.2 Students make analyses and answer questions by observing phenomena.

2. Exploration stage

This stage is the central link of the 5E inquiry-based teaching. Teachers can guide students to explore according to the cognitive conflict generated in the previous link. In the process of inquiry, students are the main body, and the role of teachers is to guide and help. Teachers should pay attention to observation, listening, and give appropriate prompts and guidance to understand the process and depth of students' inquiry, while avoiding students from drawing conclusions too quickly.

2.1 Teachers introduce the principle of red blood cell hemolysis

experiment, provide red blood cell solution (chicken blood cells with 0.85% Nacl solution), 0.085% Nacl solution students in small groups to carry out the experiment, and combined with the observed phenomena to answer the questions: (1) before and after the addition of hypotonic Nacl solution, the state of the red blood cell solution, respectively, what is the state of the red blood cell solution? (2) What is the difference between the erythrocyte solution before and after the experiment for microscopic examination? What is the reason for the rise of the red blood cells? What does this experiment show?

Students carry out the experimental operation, observe the phenomenal changes in the red blood cell solution before and after the experiment, discuss in groups, analyze and answer the questions.

Teacher: In order to further study the composition and structure of cell membranes, people extracted the components of cell membranes by centrifugation, and found that the main components of cell membranes are lipids, and are dominated by phospholipids. Then how are biological membranes composed?

The teacher plays a video to simulate the structural composition of cell membranes. And summarize with students the components and structural features of cell membranes.

Teacher's question: as the boundary of the cell as a system, what functions does the cell membrane have in life activities?

2.2 Divide the students into groups, each group independently carries out the task assignment, and at the same time conducts the following two experiments in order to investigate the functions of the cell membrane.

Experiment 1: Dialysis experiment

Teacher to provide students with materials for the experiment: homemade semi-permeable membrane bag, starch colloid and sodium chloride mixture, iodized water, silver nitrate solution. Experimental equipment: beakers, test tubes several, dropper, tweezers and so on. Combined with the two chemical reactions studied in the previous lesson, students independently design experiments to investigate the function of cell membranes (Hint: Semipermeable membranes are similar in function to cell membranes). Answer the following questions:

(1) The experiment proved that the cell membrane has what kind of function? How did you know that?

(2) Can a semipermeable membrane replace the cell membrane in the experiment? Why?

Students discuss the design of a reasonable experimental program based on what they have learned and with the guidance of the teacher. Divide the work within the group independently to carry out two experiments, observe and record the experimental phenomena. Finally, each group elects a representative to speak.

Experiment 2: Plasmic Wall Separation

The teacher will explain the principle of plasmic wall separation and provide onion epidermal mounts, 0.3g/m L sucrose solution and water. Students conduct the experiment and answer the following questions: (1) What phenomena were observed in the two solutions? Did they match your expectations? (2) What function does the experiment demonstrate that the cell membrane has?

Students will be divided into groups. Students will listen to the teacher's explanation of the basic principles, design experiments in groups, and refer to the textbook.

Students will be divided into groups and design experiments in their groups and carry out investigations with reference to the textbook.

2.3 Teacher and students summarize the functions of the cell membrane.

3. Explanation stage

The explanation stage is a key part of the 5E inquiry-based teaching. During this stage, students' attention is focused on the presentation and analysis of the inquiry process and results, providing opportunities for students to demonstrate their understanding of knowledge and their mastery of skills or application of methods, and for students to try to explain their understanding of knowledge in their own words. This stage also provides opportunities for teachers to introduce concepts, processes, or methods directly. Teachers should help students develop a deeper understanding of new knowledge with the help of the curriculum objectives.

3.1 Teacher organization inquiry activity 1: animal red blood cells into a lower concentration of salt solution, the cells a large number of water-absorbing

rupture, to the outside world to release hemoglobin, will be placed in a test tube in the light transmission, can be clearly observed from the solution from the opaque cell suspension into a red transparent hemoglobin solution, this phenomenon is called hemolysis. This phenomenon is called hemolysis. It illustrates the function of the cell membrane as the boundary of the whole cell.

3.2 Teachers organize inquiry activity 2:

Experiment 1: Chloride ions react with silver ions to produce silver chloride which appears as a white precipitate, and iodine solution turns blue when it meets starch solution. According to the principle of the reaction, 10 ml of sodium chloride solution and starch colloid mixed into the liquid added to the bag-shaped semipermeable membrane, and the semipermeable membrane into a beaker containing water, so that the water level is higher than the level of the mixture. 2 minutes later, the beaker of liquid removed from the appropriate amount and divided into two equal parts, one of which is added to the silver nitrate solution, and the other is added to iodine water. As a result, the test tube has a white turbidity, iodine solution did not turn blue, which can show that the semipermeable membrane allows chloride ions to pass through but not starch molecules. This experiment shows that the cell membrane controls the entry and exit of substances and has selective permeability.

Experiment 2: After adding sucrose solution to the edge of the coverslip, it can be observed that the large vesicles in the cell continue to shrink to a certain extent, no longer change, the cell water loss; and then add water to the edge of the coverslip, the vesicles were found to restore the size of the cell to absorb water. Again, this proves that small molecules like water can be rapidly transported across the membrane.

3.3 Through the exchange and analysis of the results of the experiments of Inquiry 1 and Inquiry 2, under the guidance of the teacher, students concluded that the cell membrane has two physiological functions, namely, controlling the entry and exit of substances, and selective permeability of substances entering and leaving the cell.

4. Elaboration stage

Under the guidance of the teacher, students continue to develop their understanding and application of knowledge, expand the basic connotations of knowledge, make certain connections to other existing knowledge, and use new knowledge to explain new situations or problems. Through practical exercises, students can deepen or expand their understanding of knowledge and gain more information and skills. When using new knowledge to explain new and similar situations or problems, students should be guided to use the terminology they have just learned as much as possible so that they can not only answer new situations and problems; they can also deepen their understanding of the new knowledge.

4.1 The teacher explains to student's which substances can be transported across membranes by free diffusion and which substances require the help of membrane transport proteins. The selective permeability of the membrane to substances is closely related to the composition and structure of the membrane.

4.2 The teacher plays an animation to show the structure of intercellular ligaments between cells, which are connected through the formation of channels between two cells.

Questions: (1) What kind of function does the animation demonstrate that cells have? (2) In what other ways can this function of cells be realized?

4.3 The teacher provides the following materials: 4 amaranth plants of similar size and condition, 2 porcelain bowls, 1 teacup, and 1 electric kettle. Students will carry out the design of the experiment according to the experimental apparatus and materials given by the teacher to investigate the role of the cell membrane of living cells in controlling the entry and exit of substances.

4.4 In this process the teacher asks probable open-ended questions to help students apply and extend the concepts in new contexts.

5. Evaluation stage

At this stage, teachers and students use formal or informal methods to evaluate students' understanding and application of new knowledge. If the evaluation is conducted in a formal way, teachers can use paper-and-pencil tests and performance tasks. If informal evaluation is adopted, teachers can conduct it at

any time during the whole teaching process. In short, the purpose of evaluation is to ensure the direction of students' activities or encourage students to reflect on the research process. At the same time, evaluation also provides teachers with an opportunity to evaluate their own teaching process and effect.

5.1 The instructor guides students through the experimental design.

5.2 Teacher evaluates students' overall performance.

5.3 Assign post-class assignments.

Instructional Media

1. Chinese General High School Textbook - Biology (Compulsory 1)

2. National primary and secondary school wisdom education platform boutique online open courses (Based on this, we will conduct online and offline mixed teaching)

Evaluation

1. Pre-test experimental design ability
2. Observe students' experimental design abilities
3. Checks for experimental design abilities while working
4. Post-lesson assignments are used to assess students' mastery in this lesson

Learning Schedule: Structure and function of cell membrane 4 hours

Date/time	Teaching Process	Remark
August 30st 2023 07.30–08.30	Pre-test subjective test	1 hour
08.30–08.40	Introduction (Structure and function of cell membrane)	10 minutes
08.40–09.10	Learning Activity: Using 5E inquiry-based teaching have 5 stages 1) Engagement stage	30 minutes
09.10–10.00	2) Exploration stage	50 minutes
10.00–10.10	Break time	
10.10–10.50	3) Explanation stage	40 minutes
10.50–11.20	4) Elaboration stage	30 minutes
11.20–11.40	5) Evaluation stag	20 minutes

Worksheet for student's Experimental Design Ability

Worksheet I

The cell membrane of living cells controls the entry and exit of substances

Cell membranes, like customs or border checkpoints, conduct a rigorous inspection of the substances entering and leaving the cells. Please design the experiment with the given experimental materials and utensils, so that it can simultaneously verify that the cell membrane of living cells has the role of controlling the entry and exit of substances.

1. Experimental materials and utensils: 4 amaranth plants of similar size and status, 2 porcelain bowls, 1 teacup, 1 electric kettle.

2. Experimental design ideas

1) Experimental purpose:

---

2) Determination of variables and relationship statement:

---

3) Experimental procedures:

---

4) Prediction and conclusion of the experimental results:

Observation form about Student behavior

Learner behavior------ Lesson Plan I
1) ability specify the purpose of an experiment ability --- --- ---
2) state the relationship of variables ability --- --- ---
3) describe the experimental procedure ability --- --- ---
4) express the expected results of an experiment ability --- --- ---

Assessment form

for Validity of the Structure and Function of Cell Membranes lesson plan

Research Title: Using 5E inquiry-based teaching to improve experimental design ability for middle school students

Research Objectives:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Directions:

Please assess the congruence between components of lesson plan based on 5E inquiry-based teaching by putting ✓ in the box according to the following criteria.

Rating is +1. There is an opinion that "consistent to relevant."

Rating is 0. There is an opinion that "Not sure it consistent to relevant."

Rating is -1. There is an opinion that "Inconsistent with relevant."

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
1	Learning objectives sort the contents from easy to difficult.				
2	5E inquiry-based teaching encourages students to work in teams and solve problems rationally.				
3	Determining content suitable for the age of students.				
4	Organizing activities suitable for learning objectives.				
5	5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.				
6	Learning activities are linked from basic knowledge to ask questions, express their real				

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
	ideas and effective discussion.				
7	The using instructional media are suitable for learning activities.				
8	The duration of the activity is appropriate for improving the experimental design ability of middle school students.				
9	Measurement and evaluation are suitable for learning activities to develop real ability.				
10	Assessment criteria are appropriate for subjective learning.				

Sign.....Assessor

(.....)

Date...../...../.....

Lesson Plan II

The first semester of the first year of high school

Department	Weifang Beichen Middle School Biology Teaching and Research Department
Course name	Biology (Compulsory I): Active transportation and endocytosis, exocytosis
Target Audience	Senior High School Year 1, Class 2
Number of students	30
Teaching Time	3 hours
Lecturer	Yin Hua

Content

Active transportation and endocytosis, exocytosis

Objective of Leaning

1. The student can identify the purpose of an experiment on active transport and endocytosis and cytotoxicity.

2. The student can state the relationship of variables in an experiment on active transport, endocytosis, and cytotoxicity.

3. The student can describe the procedure of an experiment on active transport, endocytosis, and cytotoxicity.

4. The student can express expected outcomes of experiments on active transport, endocytosis, and cytokinesis.

Main point/concept

Active transportation and endocytosis, exocytosis

Active transport is the process by which a membrane transports molecules of a substance from a low concentration to a high concentration by consuming energy is called active transport. It is the ability to use energy to transport substances

against a concentration gradient. Active transport is important for functional activities of cells, such as uptake, transport, excretion, and maintenance of certain ion concentrations. The structure that performs the task of active transport is an enzyme of a substance in the membrane, such as sodium-potassium ATPase.

Endocytosis or cytokinesis (endocytosis) is an important way for cells to acquire macromolecules and granular substances from outside the cell, and it is a physiological phenomenon commonly found in eukaryotic cells. Extracellular substances are wrapped by the plasma membrane, which is invaginated and forms membrane-enveloped vesicles, which detach from the plasma membrane and enter the cell and generate a series of physiological activities and physiological functions within the cell. Cytokinesis is closely related to a variety of life activities, such as immune response, neurotransmitter transport, cellular signal transduction, and cell and tissue metabolic homeostasis. In recent years, we have gained a deeper understanding of the function and mechanism of cytokinesis with the in-depth study of it.

Cytokinesis, also known as exoplasmic, is the intracellular degradation of the residue of exogenous substances ingested by cytokinesis and cytokinesis out of the cell.

Learning Activity

Project-based learning activities have 5 stages as follows: 1) Engagement stage, 2) Exploration stage, 3) Explanation stage, 4) Elaboration stage, and 5) Evaluation stage.

1. Engagement stage

This link is the starting link of the 5E inquiry-based teaching. In order to attract students' interest in learning tasks and stimulate students to explore actively, the 5E inquiry-based teaching generally emphasizes the creation of problem situations to stimulate students' interest in learning. The problem situation here should be connected with the real life (especially the students' life) as much as possible, and with the course content and teaching tasks. Problems in the situation can attract students and cause cognitive conflicts, thus stimulating students' interest

in actively exploring and actively constructing knowledge

1.1 The teacher displays the information, asks questions and organizes a discussion with the students:

Data 1: The concentration of iodine in the follicular epithelial cells of the thyroid gland is 20-30 times higher than that in the blood.

Question (1) Is iodine uptake by follicular epithelial cells of the thyroid gland by passive transport? Why? Question (2) Is this an exception or somewhat general in the transmembrane transport of various substances?

1.2 Teacher shows the video to trigger students' cognitive conflict and stimulate their interest in learning.

Examples related to active transport: small intestinal epithelial cells absorb glucose and amino acids against the concentration; while the concentration of K+ in human erythrocytes is 30 times higher than that in blood plasma; the concentration of K+ in cells of Verticillium chloralum is 63 times higher than that in the surrounding water environment. Such high concentration differences are the result of active cellular maintenance, so how do cells do it?

2. Exploration stage

This stage is the central link of the 5E inquiry-based teaching. Teachers can guide students to explore according to the cognitive conflict generated in the previous link. In the process of inquiry, students are the main body, and the role of teachers is to guide and help. Teachers should pay attention to observation, listening, and give appropriate prompts and guidance to understand the process and depth of students' inquiry, while avoiding students from drawing conclusions too quickly.

2.1 Teachers show animation 1, ask questions to provoke students to think: the process of the cart moving from high to low and the cart moving from low to high animation.... Teacher: relate to the experience of riding a bicycle up and down a slope, and guide students to realize that going uphill requires the help of external forces. So, what conditions might be required for the transport of substances against a concentration gradient?

2.2 Teacher shows animation 2: Various substances pass through the synthetic phospholipid bilayer, but glucose cannot pass through the structure, while

the small intestinal epithelial cells are able to absorb glucose from the blood. Then show the picture of the cell membrane flow mosaic model, and guide students to think: what components of the cell membrane are involved in transport against the concentration gradient like this?

2.3 The teacher shows an animation of the active transport process and guides students to observe the changes of carrier proteins.

Teacher: A carrier protein is usually only suitable for binding to one or a class of ions or molecules - carrier proteins are specialized. The spatial structure of carrier proteins changes when driven by energy.

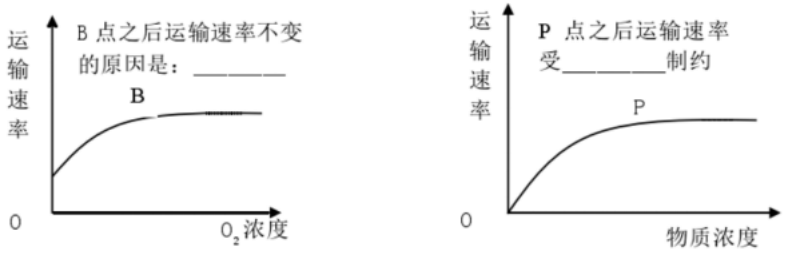
Teacher shows the process of energy-driven carrier protein transporting substances again, so that students can summarize the concept, process and characteristics of active transport.

2.4 Teacher displays the information and asks questions:

Data 2: The main cause of cystic fibrosis disease is an abnormality in the carrier protein that transports chloride ions in patients.

Data 3: K+ cannot pass through the synthetic phospholipid bilayer, but if a small amount of valinomycin (which is essentially a protein) is added and energy is provided, K+ can pass through the synthetic membrane from a low concentration to a high concentration.

Teacher questions: (1) What determines the function of proteins? (2) Combine the information and speculate on the factors that affect active transport What are they? (3) Show the graph of active transport. (4) What characteristic of the cell membrane is related to the transmembrane transport of small molecules?



2.5 The teacher explains that the type and number of carrier proteins and changes in the spatial structure of carrier proteins play a decisive role in the

transport of substances across membranes, refle cting the selective permeability of cell membranes.

2.6 Teachers again cite examples of active transport, pointing out that cells carry out active transport even if they pay a price and consume energy, which suggests that active transport is of what importance to cells and individuals?

3. Explanation stage

The explanation stage is a key part of the 5E inquiry-based teaching. During this stage, students' attention is focused on the presentation and analysis of the inquiry process and results, providing opportunities for students to demonstrate their understanding of knowledge and their mastery of skills or application of methods, and for students to try to explain their understanding of concepts in their own words. This stage also provides opportunities for teachers to introduce concepts, processes, or methods directly. Teachers should help students understand new knowledge in greater depth with the help of the curriculum objectives.

3.1 Teachers ask questions to stimulate students' motivation for further investigation: transporter proteins can transport some ions and small molecules; can large molecules also cross the cell membrane? Do students still remember the synthesis and transportation process of secretory proteins, and how secretory proteins are finally transported outside the cell? Does this process require energy?

Explain that secretory protein secretion is the process of cytokinesis.

3.2 Teachers show videos and pictures: (1) video of the process of amoeba ingestion of Cnidaria; (2) schematic diagram of amoeba phagocytosis of human cells in dysentery

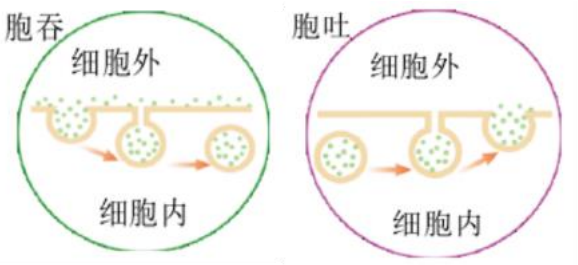
Teacher: Through the above examples of secreted proteins and amoebas, it can be seen that macromolecules like proteins and polysaccharides enter and leave the cell through cytophagy and cytotoxicity, so what is the specific process of this mode of transportation? And what are the characteristics?

3.3 Teacher assigns tasks and organizes group discussion:

Organize students to independently read the textbook "cytosol and cytosol" related content, group discussion of the following issues: (1) try to explain the process and characteristics of cytosol and cytosol (2) cytosol, cytosol and what is

the relationship between the role of the cell membrane and the structural properties of cytosol?(3) Proteins synthesized by free ribosomes (intracellular proteins) are mostly for the cell's own use, while proteins synthesized by ribosomes attached to the endoplasmic reticulum (secretory proteins) are secreted outside the cell. Try to analyze the rationale.

3.4 The teacher will display pictures. Representatives of small groups will explain the process and characteristics of cytophagy in the context of the schematic diagram.



Teacher's Addendum: Cytophagy requires that macromolecules recognize each other and proteins in the membrane to accomplish transmembrane transport in an energy-driven manner.

4. Elaboration stage

Under the guidance of the teacher, students continue to develop their understanding and application of knowledge, expand the basic connotations of knowledge, make certain connections to other existing knowledge, and use new knowledge to explain new situations or problems. Through practical exercises, students can deepen or expand their understanding of knowledge and gain more information and skills. When explaining new and similar situations or problems with new knowledge, students should be guided to use the terminology they have just learned as much as possible so that they can not only answer new situations and problems; they can also deepen their understanding of the new knowledge.

4.1 The teacher provides the following materials: a number of fresh radish strips of equal size and length, a number of small beakers with the same scale, a cup of water, a cup of thick salt water, a fresh bag, a tweezers, a ruler. Students will carry out an experimental design based on the experimental apparatus and materials

provided by the teacher to explore the effect of external solution concentration on the water absorption of root cells

4.2 During this process, the teacher reminds students to set up a control group and asks possible open-ended questions to help students apply and extend the concepts in new contexts.

5. Evaluation stage

At this stage, teachers and students use formal or informal methods to evaluate students' understanding and application of new knowledge. If the evaluation is conducted in a formal way, teachers can use paper-and-pencil tests and performance tasks. If informal evaluation is adopted, teachers can conduct it at any time during the whole teaching process. In short, the purpose of evaluation is to ensure the direction of students' activities or encourage students to reflect on the research process. At the same time, evaluation also provides teachers with an opportunity to evaluate their own teaching process and effect.

5.1 Students are encouraged to actively share what they have learned in class.

5.2 Teacher evaluates students' overall performance.

5.2 Assign post-lesson homework.

Instructional Media

1. Chinese General High School Textbook - Biology (Compulsory 1)

2. National primary and secondary school wisdom education platform boutique online open courses (Based on this, we will conduct online and offline mixed teaching)

Evaluation

1. Observe students' experimental design abilities
2. Checks for experimental design abilities while working
3. Post-lesson assignments are used to assess students' mastery in this lesson

Learning Schedule: Active transportation and endocytosis, exocytosis 3 hours

Date/time	Teaching Process	Remark
September 1th 2023 08.00–08.10	Introduction (Active transportation and endocytosis, exocytosis)	10 minutes
08.10–08.40	Learning Activity: Using 5E inquiry-based teaching have 5 stages 1) Engagement stage	30 minutes
08.40–09.30	2) Exploration stage	50 minutes
09.30–-09.40	Break time	
09.40–10.20	3) Explanation stage	40 minutes
10.20–10.50	4) Elaboration stage	30 minutes
10.50–11.10	5) Evaluation stag	20 minutes

Worksheet for student's Experimental Design Ability

Worksheet II

To explore the effect of the external solution concentration on the water absorption of the root cells

1. Experimental materials and utensils: a number of fresh radish strips of equal size and length, a number of small beakers with the same scale, a cup of water, a cup of thick salt water, a fresh bag, a tweezers, a ruler.

2. Experimental design ideas

1) Experimental purpose:

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2) Determination of variables and relationship statement:

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3) Experimental procedures:

---

4) Prediction and conclusion of the experimental results:

Observation form about Student behavior

Learner behavior------ Lesson Plan II
1) ability specify the purpose of an experiment ability --- --- ---
2) state the relationship of variables ability --- --- ---
3) describe the experimental procedure ability --- --- ---
4) express the expected results of an experiment ability --- --- ---

Assessment form

for Validity of the Active transportation and endocytosis, exocytosis lesson plan

Research Title: Using 5E inquiry-based teaching to improve experimental design ability for middle school students

Research Objectives:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Directions:

Please assess the congruence between components of lesson plan based on 5E inquiry-based teaching by putting ✓ in the box according to the following criteria.

Rating is +1. There is an opinion that “consistent to relevant.”

Rating is 0. There is an opinion that “Not sure it consistent to relevant.”

Rating is -1. There is an opinion that “Inconsistent with relevant.”

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
1	Learning objectives sort the contents from easy to difficult.				
2	5E inquiry-based teaching encourages students to work in teams and solve problems rationally.				
3	Determining content suitable for the age of students.				
4	Organizing activities suitable for learning objectives.				
5	5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.				
6	Learning activities are linked from basic knowledge to ask questions, express their real				

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
	ideas and effective discussion.				
7	The using instructional media are suitable for learning activities.				
8	The duration of the activity is appropriate for improving the experimental design ability of middle school students.				
9	Measurement and evaluation are suitable for learning activities to develop real ability.				
10	Assessment criteria are appropriate for subjective learning.				

Sign.....Assessor

(.....)

Date...../...../.....

Lesson Plan III

The first semester of the first year of high school

Department	Weifang Beichen Middle School Biology Teaching and Research Department
Course name	Biology (Compulsory I): Enzymes that reduce the activation energy of chemical reactions
Target Audience	Senior High School Year 1, Class 2
Number of students	30
Teaching Time	3 hours
Lecturer	Yin Hua

Content

Enzymes that reduce the activation energy of chemical reactions

Objective of Leaning

1. The student can identify the purpose of an experiment on enzymes that reduce the activation energy of a chemical reaction.

2. The student can state the relationship of variables in an experiment on enzymes that reduce the activation energy of a chemical reaction.

3. The student can describe the procedure of an experiment on enzymes that reduce the activation energy of a chemical reaction.

4. The student can express expected results of experiments on enzymes that reduce the activation energy of chemical reactions.

Main point/concept

Enzymes that reduce the activation energy of chemical reactions

Enzymes are catalytic organic substances produced by living cells, the vast majority of which are proteases. Instead of supplying energy, enzymes lower the activation energy of a reaction, promote the reaction, shorten the completion time,

and are not consumed themselves, and the reaction results are consistent with the absence of a catalyst. Compared to inorganic catalysts, enzymes reduce activation energy more significantly and thus catalyze more efficiently.

Learning Activity

Project-based learning activities have 5 stages as follows: 1) Engagement stage, 2) Exploration stage, 3) Explanation stage, 4) Elaboration stage, and 5) Evaluation stage.

1. Engagement stage

This link is the starting link of the 5E inquiry-based teaching. In order to attract students' interest in learning tasks and stimulate students to explore actively, the 5E inquiry-based teaching generally emphasizes the creation of problem situations to stimulate students' interest in learning. The problem situation here should be connected with the real life (especially the students' life) as much as possible, and with the course content and teaching tasks. Problems in the situation can attract students and cause cognitive conflicts, thus stimulating students' interest in actively exploring and actively constructing knowledge.

1.1 Teachers set up a situation to stimulate students' interest in learning: Teachers play a video advertisement of enzyme-enriched laundry detergent and ask: "Have students used enzyme-enriched laundry detergent? Why is enzyme laundry detergent more effective? What is enzyme?

1.2 Ask questions to arouse students' desire to investigate. Guide students to recall the relevant knowledge of chemistry and play the video related to the synthesis of oxygen in industry. Ask question 1: What conditions are needed to synthesize ammonia in industry? Ask Question 2: Why do people lose their appetite when they have a fever? Can we use such experimental conditions in the human body in order to eliminate food?

1.3 The teacher guides students to recall what they have learned about digestive enzymes in junior high school, and asks the question: what are the conditions that affect the activity of enzymes?

2. Exploration stage

This stage is the central link of the 5E inquiry-based teaching. Teachers can guide students to explore according to the cognitive conflict generated in the previous link. In the process of inquiry, students are the main body, and the role of teachers is to guide and help. Teachers should pay attention to observation, listening, and give appropriate prompts and guidance to understand the process and depth of students' inquiry, while avoiding students from drawing conclusions too quickly.

2.1 Experience exploratory experimental activity 1: students will be divided into groups of four, to be formally proposed by the groups want to investigate the problem, make assumptions, design a good experimental program, the teacher to provide the necessary experimental equipment and experimental materials, such as soluble starch solution, amylase solution, hydrogen peroxide solution, hydrogen peroxide enzyme, Ferrin's reagent, iodine solution, hydrochloric acid, sodium hydroxide solution, and a water bath, etc.. Teachers pay attention to the guidance of the groups when they carry out the process of experimental investigation.

2.2 Experiencing Exploratory Experimental Activity 2: Through the previous exploratory activity, students conclude that the conditions affecting enzyme activity are temperature, PH, etc. The teacher raises the question: cells contain a catalase enzyme, which can decompose harmful substances produced by cells, such as hydrogen peroxide, into oxygen and water in a timely manner. What is special about this enzyme compared to inorganic catalysts in chemistry?

2.3 The teacher needs to provide suitable experimental materials and guide students to complete the experimental design, paying attention to timely questions.

3. Explanation stage

The explanation stage is a key part of the 5E inquiry-based teaching. During this phase, students' attention is focused on the presentation and analysis of the process and results of the inquiry, providing opportunities for students to demonstrate their understanding of knowledge and their mastery of skills or methods, and for them to try to explain their understanding of the content of the experiment in their own words. This stage also provides opportunities for teachers to introduce concepts, processes, or methods directly. The teacher should help

students understand the new knowledge in greater depth with the help of the curriculum objectives.

3.1 The teacher encourages students to express their understanding of the concept. Teachers before the class arranged the interest group students to preview the textbook P81 "about the nature of the enzyme exploration" part of the content, and let the students through role-playing, in the form of a textbook drama to show the five scientists Pasteur, Lippincott, Bichner, Sumner, Ottman, the nature of the enzyme exploration process. The students will watch and think about the process and give a complete definition of "enzyme" in relation to the results of the investigation process.

3.2 The teacher gives a direct scientific explanation of the concept. After the students have actively discussed and spoken, the teacher will give a precise definition of "enzyme" directly. At the same time, the teacher summarizes the role and characteristics of enzymes in cellular metabolism to help students build a complete knowledge framework.

4. Elaboration stage

Under the guidance of the teacher, students continue to develop their understanding and application of knowledge, expand the basic connotations of knowledge, make certain connections to other existing knowledge, and use new knowledge to explain new situations or problems. Through practical exercises, students can deepen or expand their understanding of knowledge and gain more information and skills. When explaining new and similar situations or problems with new knowledge, students should be guided to use the terminology they have just learned as much as possible so that they can not only answer new situations and problems; they can also deepen their understanding of the new knowledge.

4.1 The teacher provides the following information: starch solution, amylase solution, water bath, a few test tubes, test tube clip, iodine liquid. Students design and complete the experiment according to the experimental apparatus and materials given by the teacher to test their hypothesis.

4.2 In this process the teacher asks probable open-ended questions to help students apply and extend the concepts in new contexts.

5. Evaluation stage

At this stage, teachers and students use formal or informal methods to evaluate students' understanding and application of new knowledge. If the evaluation is conducted in a formal way, teachers can use paper-and-pencil tests and performance tasks. If informal evaluation is adopted, teachers can conduct it at any time during the whole teaching process. In short, the purpose of evaluation is to ensure the direction of students' activities or encourage students to reflect on the research process. At the same time, evaluation also provides teachers with an opportunity to evaluate their own teaching process and effect.

5.1 Students are encouraged to actively share what they have learned in class.

5.2 Teacher evaluates students' overall performance.

5.2 Assign post-lesson homework.

Instructional Media

1. Chinese General High School Textbook - Biology (Compulsory 1)

2. National primary and secondary school wisdom education platform boutique online open courses (Based on this, we will conduct online and offline mixed teaching)

Evaluation

1. Observe students' experimental design abilities

2. Checks for experimental design abilities while working

3. Post-lesson assignments are used to assess students' mastery in this lesson

Learning Schedule: Enzymes that reduce the activation energy of chemical reactions 3 hours

Date/time	Teaching Process	Remark
September 6th 2023 08.00–08.10	Introduction (Enzymes that reduce the activation energy of chemical reactions)	10 minutes
08.10–08.40	Learning Activity: Using 5E inquiry-based teaching have 5 stages 1) Engagement stage	30 minutes
08.40–09.30	2) Exploration stage	50 minutes
09.30–09.40	Break time	
09.40–10.20	3) Explanation stage	40 minutes
10.20–10.50	4) Elaboration stage	30 minutes
10.50–11.10	5) Evaluation stag	20 minutes

Worksheet for student's Experimental Design Ability

Worksheet III

To explore the effect of temperature on the enzyme activity

It is known that almost all chemical reactions in a cell are catalyzed by enzymes, and the catalytic efficiency of enzymes to chemical reactions is called enzyme activity. Cells live in a certain environment; will the change of environmental conditions affect the activity of cellular enzymes?

1. Experimental materials and utensils: starch solution, amylase solution, water bath, a few test tubes, test tube clip, iodine liquid. Please use the given experimental materials and utensils to design experiments to explore the effect of temperature on the enzyme activity.

2. Experimental design ideas

1) Experimental purpose:

---

2) Determination of variables and relationship statement:

---

3) Experimental procedures:

---

4) Prediction and conclusion of the experimental results:

Observation form about Student behavior

Learner behavior------ Lesson Plan III
1) specify the purpose of an experiment --- --- --- ---
2) state the relationship of variables --- --- --- ---
3) describe the experimental procedure --- --- --- ---
4) express the expected results of an experiment ability --- --- --- ---

Assessment form

for Validity of the enzymes that reduce the activation energy of chemical reactions lesson plan

Research Title: Using 5E Inquiry Based inquiry-based teaching to improve experimental design ability for middle school students

Research Objectives:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Directions:

Please assess the congruence between components of lesson plan based on 5E inquiry-based teaching by putting ✓ in the box according to the following criteria.

Rating is +1. There is an opinion that "consistent to relevant."

Rating is 0. There is an opinion that "Not sure it consistent to relevant."

Rating is -1. There is an opinion that "Inconsistent with relevant."

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
1	Learning objectives sort the contents from easy to difficult.				
2	5E inquiry-based teaching encourages students to work in teams and solve problems rationally.				
3	Determining content suitable for the age of students.				
4	Organizing activities suitable for learning objectives.				
5	5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.				

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
6	Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.				
7	The using instructional media are suitable for learning activities.				
8	The duration of the activity is appropriate for improving the experimental design ability of middle school students.				
9	Measurement and evaluation are suitable for learning activities to develop real ability.				
1 0	Assessment criteria are appropriate for subjective learning.				

Sign.....Assessor

(.....)

Date...../...../.....

Lesson Plan IV

The first semester of the first year of high school

Department	Weifang Beichen Middle School Biology Teaching and Research Department
Course name	Biology (Compulsory I): Photosynthesis and energy conversion
Target Audience	Senior High School Year 1, Class 2
Number of students	30
Teaching Time	3 hours
Lecturer	Yin Hua

Content

Photosynthesis and energy conversion

Objective of Leaning

1. The student can identify the purpose of experiments related to photosynthesis and energy conversion

2. The student can state the relationship of variables in an experiment on photosynthesis and energy conversion.

3. The student can describe experimental procedures related to photosynthesis and energy conversion.

4. The student can express expected results of experiments on photosynthesis and energy conversion.

Main point/concept

Photosynthesis and energy conversion

Photosynthesis is the process by which green plants, through chloroplasts, use light energy to convert carbon dioxide and whoever into organic matter with stored energy and to release oxygen. It mainly includes two stages of light reaction and dark reaction, involving light absorption, electron transfer, photosynthetic

phosphorylation, carbon assimilation and other important reaction steps, which are important to realize energy conversion in nature and maintain the carbon-oxygen balance in the atmosphere.

Energy conversion means that energy can neither arise nor disappear out of thin air in a fixed and closed environment, and energy conversion means the transformation from one form to another or the transfer from one object to another. Energy appears in many forms, including radiation, motion of objects, atoms in an excited state, and strain forces within and between molecules. The importance of all these forms is that their energies are equal, meaning that one form of energy can be transformed into another form. The vast majority of events that occur in the universe, such as the collapse and explosion of stars, the growth and destruction of living things, and the operation of machines and computers, include the transformation of energy from one form to another.

Learning Activity

Project-based learning activities have 5 stages as follows: 1) Engagement stage, 2) Exploration stage, 3) Explanation stage, 4) Elaboration stage, and 5) Evaluation stage.

1. Engagement stage

This link is the starting link of the 5E inquiry-based teaching. In order to attract students' interest in learning tasks and stimulate students to explore actively, the 5E inquiry-based teaching generally emphasizes the creation of problem situations to stimulate students' interest in learning. The problem situation here should be connected with the real life (especially the students' life) as much as possible, and with the course content and teaching tasks. Problems in the situation can attract students and cause cognitive conflicts, thus stimulating students' interest in actively exploring and actively constructing knowledge

1.1 Teacher introduces the theme of this lesson: we watch this picture, which is located in Tong Zhou City, a factory, which subverted the traditional way of planting vegetables, the use of LED artificial light to plant vegetables, this environment can be adjusted through the computer, the production is much less

difficult, in the light of LED lights, plants thrive.

And then lead to the theme of this experimental lesson, plants rely on which pigments to capture light energy.

1.2 Teacher's question: For the birch seedlings that do not contain green pigments die quickly, is this related to the pigments in the leaves for light energy capture?

1.3 Teacher's question to the class: Through previous study we know that the chloroplasts of green plants contain various pigments needed for photosynthesis, so how do we extract and separate these pigments?

2. Exploration stage

This stage is the central link of the 5E inquiry-based teaching. Teachers can guide students to explore according to the cognitive conflict generated in the previous link. In the process of inquiry, students are the main body, and the role of teachers is to guide and help. Teachers should pay attention to observation, listening, and give appropriate prompts and guidance to understand the process and depth of students' inquiry, while avoiding students from drawing conclusions too quickly.

2.1 The teacher begins by asking for the purpose of the experiment:

(1) to extract and separate the pigments in green leaves

(2) to investigate how many pigments are found in green leaves.

2.2 The teacher leads the students to investigate whether anhydrous ethanol can extract the pigments in spinach. Ask the class to think about how we should verify whether anhydrous ethanol can extract pigments from spinach, taking into account their existing experience.

2.3 Teachers conduct experiments and guide students to observe the realization of the elephant: take out two beakers of the same size prepared before class, put water into one of the beakers and countless ethanol into the other, put

two pieces of white cloth dyed with spinach juice into the two beakers respectively, and after a period of time, let the students observe the color of the white cloth. Thus, verifying that anhydrous ethanol can indeed dissolve the pigment in it.

2.4 The teacher explains the experimental notes on the extraction and separation of pigments from green leaves.

2.5 The teacher instructs the students to recall and combine the book about the controlled variable method and determine the different variables of this experiment according to the principle.

2.6 The teacher lets the students carry out the experiment on their respective lab benches according to the experimental groups divided before class, and the experiment is divided into the following steps:

(1) Determine the experimental materials: students determine if there are any missing or broken materials such as chromatography solution, anhydrous ethanol, filter paper, mortar and pestle, glass funnel, nylon cloth, dental floss, scissors, medicine spoon, measuring cylinder (10 ml), balance, pencil, Petri dish, silica and sodium carbonate, spinach, and round rod of filter paper, etc., that have been prepared in advance in the laboratory.

(2) Weigh 3g of spinach leaves and reduce them to a mortar. Add a small amount of silica and calcium carbonate to the mortar and then add 5

Add a small amount of silica and calcium carbonate to the mortar, and then add about 5 ml of anhydrous ethanol and grind quickly.

What is the role of silica and calcium carbonate?

(3) Take out the funnel, put a single layer of nylon cloth on top of the funnel, and pour the grinding liquid into the funnel quickly for filtration. Collect the filtrate in a test tube and close it tightly.

(4) Prepare a strip of filter paper, slightly narrower in width and length than the width of the test tube. Subtract two corners from one end of the strip and draw a thin horizontal line with a pencil 1 cm up from the bottom of the strip.

(5) Dip the end of the dental floss into a small amount of the filtrate and repeat the line two or three times on the horizontal line.

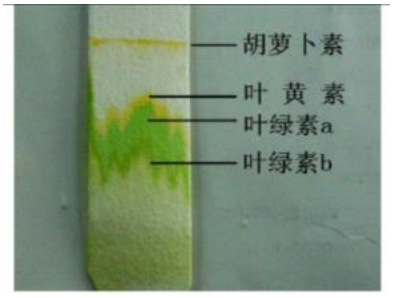
(6) Put an appropriate amount of laminar solution into the test tube, insert

the strip of filter paper just cut into the laminar solution, but do not let the thin line of filtrate touch the laminar solution, and finally plug it with a cotton swab. Observe the bands of pigment appearing on the strip of filter paper, as well as the color and width of each band of pigment, and record them in your notes.

3. Explanation stage

The explanation stage is a key part of the 5E inquiry-based teaching. During this phase, students' attention is focused on the presentation and analysis of the process and results of the inquiry, providing opportunities for students to demonstrate their understanding of knowledge and their mastery of skills or methods, and for them to try to explain their understanding of the content of the experiment in their own words. This stage also provides opportunities for teachers to introduce concepts, processes, or methods directly. Teachers should help students gain a deeper understanding of new knowledge with the help of the curriculum objectives.

3.1 Teacher's explanation: the width of the pigment bands on the filter paper strips shows the number of various pigments. The results of the experiment found that there are four pigment bands on the filter paper strip, from more to less chlorophyll a, chlorophyll b, lutein, carotene. The solubility of the pigments can be seen from the order of the pigment bands on the filter paper strips, and the solubility of the pigments in descending order is carotene, lutein, chlorophyll a, chlorophyll b. The solubility of the pigments can be seen from the order of the pigment bands on the filter paper strips.



3.2 The teacher guides students to draw conclusions from the experiment and asks representatives of each group to share their results.

4. Elaboration stage

Under the guidance of the teacher, students continue to develop their

understanding and application of knowledge, expand the basic connotations of knowledge, make certain connections to other existing knowledge, and use new knowledge to explain new situations or problems. Through practical exercises, students can deepen or expand their understanding of knowledge and gain more information and skills. When using new knowledge to explain new and similar situations or problems, students should be guided to use the terminology they have just learned as much as possible so that they can not only answer new situations and problems; they can also deepen their understanding of the new knowledge.

4.1 The teacher guides the students to think: Why don't we use green light sources in plant factories? Students can answer this question by combining the textbook with the percentage of light energy absorbed by each pigment.

4.2 The teacher asks the question: why is it necessary to add silica and calcium carbonate when grinding, and what are their functions respectively? Students can think about this question in relation to the characteristics of green leaves and pigments.

4.3 Under the guidance of the teacher, the students will answer the question through the derived experimental results and discuss and analyze them.

4.4 The teacher provides the following materials: leaves of fava beans of comparable leaf age, drills, beakers, syringes, lamps of different wattages, tweezers, $NaHCO_3$ of different concentrations, distilled water, thermometers, alcohol lamps. Students carry out the design of the experiment according to the experimental apparatus and materials given by the teacher to investigate the factors affecting photosynthesis

4.5 In this process the teacher asks probable open-ended questions to help students apply and extend the concepts in new contexts.

5. Evaluation stage

At this stage, teachers and students use formal or informal methods to evaluate students' understanding and application of new knowledge. If the evaluation is conducted in a formal way, teachers can use paper-and-pencil tests and performance tasks. If informal evaluation is adopted, teachers can conduct it at any time during the whole teaching process. In short, the purpose of evaluation is to

ensure the direction of students' activities or encourage students to reflect on the research process. At the same time, evaluation also provides teachers with an opportunity to evaluate their own teaching process and effect.

5.1 The instructor guides students through the experimental design.

5.2 Teacher evaluates students' overall performance.

5.3 Assign post-class assignments.

The teacher explains to the students at the end of the lesson the purpose and manner in which the experimental design ability assessment will be conducted and distributes the assessment questions, which the students will be asked to complete in 1 hour.

Instructional Media

1. Chinese General High School Textbook - Biology (Compulsory 1)

2. National primary and secondary school wisdom education platform boutique online open courses (Based on this, we will conduct online and offline mixed teaching)

Evaluation

1. Observe students' experimental design abilities
2. Checks for experimental design abilities while working
3. Post-lesson assignments are used to assess students' mastery in this lesson
4. Post-test experimental design ability

Learning Schedule: Photosynthesis and energy conversion 4 hours

Date/time	Teaching Process	Remark
September 8th 2023 08.00–08.10	Introduction (Photosynthesis and energy conversion)	10 minutes
08.10–08.40	Learning Activity: Using 5E inquiry-based teaching have 5 stages 1) Engagement stage	30 minutes
08.40–09.30	2) Exploration stage	50 minutes
09.30–09.40	Break time	
09.40–10.20	3) Explanation stage	40 minutes
10.20–10.50	4) Elaboration stage	30 minutes
10.50–11.10	5) Evaluation stag	20 minutes
11.10–12.10	Post-test subjective test	1 hour

Worksheet for student's Experimental Design Ability

Worksheet IV

Exploring the factors affecting photosynthesis

1. Experimental materials and utensils: Broad bean leaves of comparable leaf age, drills, beakers, syringes, lamps of different power, forceps, $NaHCO_3$ of different concentrations, distilled water, thermometers, alcohol lamps.

2. Experimental design ideas

1) Experimental purpose:

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2) Determination of variables and relationship statement:

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3) Experimental procedures:

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4) Prediction and conclusion of the experimental results:

Observation form about Student behavior

Learner behavior------ Lesson Plan IV
1) specify the purpose of an experiment ability ---------- ---------- ---------- ----------
2) state the relationship of variables ability ---------- ---------- ---------- ----------
3) describe the experimental procedure ability ---------- ---------- ---------- ----------
4) express the expected results of an experiment ability ---------- ---------- ---------- ----------

Assessment form

for Validity of the Photosynthesis and energy conversion lesson plan

Research Title: Using 5E inquiry-based teaching to improve experimental design ability for middle school students

Research Objectives:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Directions:

Please assess the congruence between components of lesson plan based on 5E inquiry-based teaching by putting ✓ in the box according to the following criteria.

Rating is +1. There is an opinion that “consistent to relevant.”

Rating is 0. There is an opinion that “Not sure it consistent to relevant.”

Rating is -1. There is an opinion that “Inconsistent with relevant.”

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
1	Learning objectives sort the contents from easy to difficult.				
2	5E inquiry-based teaching encourages students to work in teams and solve problems rationally.				
3	Determining content suitable for the age of students.				
4	Organizing activities suitable for learning objectives.				
5	5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.				

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
6	Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.				
7	The using instructional media are suitable for learning activities.				
8	The duration of the activity is appropriate for improving the experimental design ability of middle school students.				
9	Measurement and evaluation are suitable for learning activities to develop real ability.				
10	Assessment criteria are appropriate for subjective learning.				

Sign.....Assessor

(.....)

Date...../...../.....

Experimental Design Ability Assessment

Middle School 30 Students

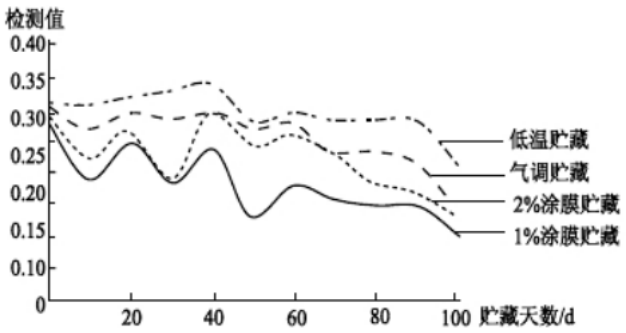
Pretest – Posttest

Examination purpose	examination
Purpose 1: Students can specify the purpose of an experiment	1,2
Purpose 2: Students can state the relationship of variables	3,4
Purpose 3: Students can describe the experimental procedure	5,6
Purpose 4: Students can express the expected results of an experiment	7,8

Clarification

Please answer the questions according to the title, each question is worth 3 points, 4 questions in total, 12 points in total.

1. Korla balsam pear fruit exists in the free state and combined state two categories of aromatic substances. Most of the combined state of aroma substances in the form of glycosides, no aroma, but in β-D-glucosidase can be decomposed under the action of the release of volatile free state of aroma substances. If the above transformation process is rapid during the storage of pears, it will lead to the loss of some of the aroma components, affecting the flavour and quality of the fruit. Researchers have carried out related experiments (the results are shown in the figure below), please analyse the answer:



The purpose of this experiment: .....

2. Newly harvested rice is cooked with an attractive aroma, but unscrupulous traders can also use rice polishing and whitening, oiled to deceive consumers. Hydrogen peroxidase activity is significantly higher in new rice than in old rice. Hydrogen peroxidase in the plant body in the presence of hydrogen peroxide (H_20_2) can be some phenolic compounds such as guaiacol oxidized into reddish-brown substances, simply expressed: guaiacol a reddish-brown substance, the color of the depth and enzyme activity is positively correlated. Now the food hygiene and quality inspectors have designed a simple experiment to test whether the rice soup is new rice.

If you had participated in this experiment, could you articulate what was the achievement of the experiment?

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3. A biology interest group is carrying out a study on "the effect of different concentrations of growth hormone analogue on seed germination and seedling growth", and the teacher has prepared a concentrated solution of growth hormone analogue and radish seeds for them. If you are one of them, please answer:

3.1 To determine the effect of growth hormone analogue on seed germination and seedling growth, you can use the measurement indexes....., ...and so on.

3.2 How would you set up a control group when doing this experiment?

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4. It has been found that UV light inhibits plant growth, probably because it increases the activity of indoleacetic acid oxidase in plants. Thus, it catalyzes the oxidation of growth hormone to 3-methylene oxindole and loses its role in promoting cell elongation. Now the teacher provides a number of wheat seedlings of the same

growth condition and healthy as experimental materials to investigate the UV inhibition of plant growth related to the oxidation of growth hormone.

Based on the experimental information provided, determine what are the independent and dependent variables in this experiment? And briefly explain how you would set up the control group?

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5. The seeds of a plant are known to be affected by water, temperature and oxygen, but it is not known whether their germination is related to light. To investigate the effect of the presence or absence of light on the germination of this seed, design the methodological steps of the experiment based on the materials and supplies given:

Materials and supplies: a sufficient number of petri dishes lined with filter paper, sterile water, surface-sterilized seeds, etc.

The methodological steps of the experiment:

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6. Glucagon has the same physiological effect on mice and humans. In order to verify that "glucagon has the physiological effect of elevating blood glucose", please design an experiment using mice as the test object.

(1) Experimental materials and equipment:2 normal mice, saline, glucagon solution prepared with saline at the appropriate concentration, Ban's glucose characterization reagent, syringes, test tubes, beakers and so on.

(2) Experimental steps:(Experimental tips: use intraperitoneal injection to give the drug, the dose of the drug is not required for the experimental design; 1 hour after the administration of the drug, use a syringe to take urine by puncture at the bladder of the mice)

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7. A student wondered whether temperature could affect the activity of thyroxine by associating it with the ability of temperature to affect enzyme activity. To explore this question, he conducted an experiment. Predict the experimental phenomena and conclusions based on the experimental steps given.

Experimental steps.

(1) Take three identical clean glass cylinders, numbered, and fill each with equal amount of river water.

(2) Take 15 tadpoles with the same developmental status, divide them into three equal parts, and put them into glass tanks No. 1, 2 and 3 respectively, and cultivate the three glass tanks under the same suitable external conditions.

(3) Every day, equal amounts of normal feed, feed mixed with thyroid preparation, and feed mixed with thyroid preparation treated with 60℃ warm waters for 1 hour were put into No.1, 2 and 3 glass tanks at the same time.

(4) Compare the development of tadpoles after a few days.

Predict the experimental phenomena and conclusions:

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8.In order to verify the physiological role of thyroid hormone, try to the rat's oxygen consumption and activity as an indicator of observation, please give you according to the experimental materials and appliances, experimental methods and steps, predict the results of the experiment, and make an analysis.

Materials and appliances: two groups of male adult rats of the same age and similar weight, thyroid hormone solution, distilled water, gavage, oxygen consumption measurement device, small animal activity meter, etc. (Experimental hints: the route of administration was daily gavage, the dose administered and the instrumentation, not required for the exam, was constant room temperature.).

Methods and steps:

(1) Two groups of male adult rats were labeled as Group A and Group B. Oxygen consumption and activity were measured and recorded with the given apparatus, respectively.

(2) Group A rats were given thyroid hormone solution by gavage and group B rats were given equal amount of distilled water by gavage daily for a certain period of time.

(3) The oxygen consumption and activity of rats in groups A and B were measured and recorded.

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Answers to the Experimental Design Ability Assessment

1. The purpose of this experiment was to study the changing law of β-D-glucosidase content (β-D-glucosidase activity) under different storage conditions.

2. The purpose of this experiment was to study the effect of different conditions on the enzyme catalase.

3. (1) Seed germination rate, length of young roots

(2) Experimental groups with different concentrations of growth hormone analogs and distilled water cross controls.

4. (1) The independent variables are equal intensities of visible light and a certain intensity of ultraviolet light. The dependent variable is the curvature of the germinal sheaths

(2) Experimental groups with different light conditions were compared with each other

5. The methodological steps of the experiment are:

(1) Pour an appropriate amount of water into the petri dish, and put an equal number of seeds into two groups of petri dishes.

(2) Place one group in a light environment, the other group in a dark environment, in the process of cultivation, so that the two groups in the temperature, water, air conditions are appropriate and the same.

6. The methodological steps of the experiment are:

(1) Identify 1 mouse as the experimental mouse, injected intraperitoneally with glucagon solution, and the other mouse as the control mouse, injected intraperitoneally with an equal volume of saline.

(2) Number the two test tubes as No. 1 and No. 2, and add an equal amount of Ferring's reagent to each.

(3) After 1 hour of drug administration, urine was collected from the two mice, and the urine of the experimental mice was put into No. 1 test tube, and the urine of the control mice was put into No. 2 test tube.

(4) The two test tubes were shaken well and put into a beaker containing boiling water to be heated and boiled, and then cooled down to observe the changes in

the color of the solutions in the two test tubes.

7. The predicted results and analysis of this experiment are:

(1) If the tadpoles in glass tank B develop fastest, while the tadpoles in glass tanks A and C develop the same, indicating that the high temperature inactivates the thyroid preparation.

(2) If the tadpoles develop fastest in glass tank B, second fastest in glass tank C, and slowest in glass tank A, then the high temperature decreases the activity of the thyroid preparation.

8. Prediction of results: when no thyroid hormone was given, the oxygen consumption and activity of rats in groups A and B were similar. After the administration of thyroid hormone to rats in Group A, their oxygen consumption and activity level were greater than those in Group B.

Analysis of results: thyroid hormone can promote metabolism, accelerate the oxidation and decomposition of substances in the body, and increase the excitability of the nervous system, thus increasing oxygen consumption and activity.

Experimental Design Ability Rating Form

Evaluation Items	Evaluation Content	Score and criterion		
		3	2	1
specify the purpose of an experiment ability	Clearly formulate questions and make assumptions	Able to give reasons for the questions and hypotheses that have been asked, and the reasons are scientifically sound	Although reasons can be given for the questions and hypotheses that have been asked, the reasons are not scientifically sound enough	Although questions and hypotheses can be asked, they are not well reasoned

Evaluation Items	Evaluation Content	Score and criterion		
		3	2	1
state the relationship of variables ability	Indicate the independent, dependent and irrelevant variables and their correspondences, in line with the single variable principle	Able to name all the variables and indicate the relationship of change, follows the single variable principle, and can satisfy the purpose of the experiment	Able to name some of the variables and point out the relationship of change, following the principle of a single variable, and basically fulfilling the purpose of the experiment	Able to name all the variables but unable to point out the relationship of change, although following the principle of a single variable, it does not fulfil the purpose of the experiment
describe the experimental procedure ability	Write down developed experimental ideas into logical, practical and specific experimental steps, consider what to look for in an experiment, and ensure that the operation is	Able to write down developed experimental ideas into logical, practical and specific experimental steps, as well as being able to consider what to look for in an experiment so as to ensure that the operation is	Able to write down developed experimental ideas into logical, practical and specific experimental steps, but unable to consider comprehensively the problems that should be noted in the experiment, and	The process of writing the formed experimental ideas into experimental steps lacks a certain logic and practicality, fails to comprehensively consider the problems that should be paid attention to in the experiment,

Evaluation Items	Evaluation Content	Score and criterion		
		3	2	1
	scientific and rigorous.	scientifically sound and rigorous.	the operation lacks scientific and ragout.	and the operation lacks scientific and ragout.
express the expected results of an experiment ability	Predict possible experimental phenomena and explain the conclusions indicated by these phenomena, or apply experimental principles to explain the causes of different phenomena.	Able to accurately predict possible experimental phenomena and explain the conclusions indicated by these phenomena, or apply experimental principles to explain the causes of different phenomena.	Able to accurately predict experimental phenomena that may occur, but unable to clearly explain the conclusions indicated by these phenomena, or apply experimental principles to explain the causes of different phenomena.	While predicting possible experimental phenomena, they are not sufficiently accurate, nor are they able to clearly explain the conclusions indicated by these phenomena, or to apply experimental principles to explain the causes of different phenomena.

Evaluate quality standards

Score Range	Quality Level
23-24	Strong
19-22	Relatively strong
15-18	General
11-14	Relatively weak
8-10	Weak

Consistency of the Expert Review Form Assessment
Variables measuring Experimental Design Ability of
first year of senior high school students.

Directions:

Please check the correspondence/appropriateness of the variables to be investigated against the definition of experimental design ability. Please put a "√" in the box to assess the consistency of the experimental design ability variable among first year of senior high school students based on the following criteria.

Rating is +1. There is an opinion that "consistent to relevant."

Rating is 0. There is an opinion that "Not sure it consistent to relevant."

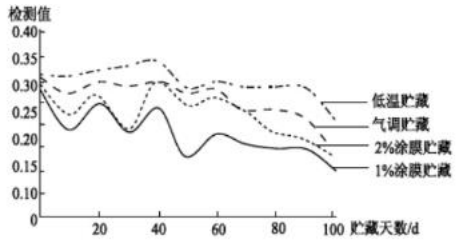
Rating is -1. There is an opinion that "Inconsistent with relevant."

Part 1 Defines the main variables of Experimental Design Ability.

variable/indicator	Define	Expert			Suggestion
		+1	0	-1	
1. specify the purpose of an experiment ability	Be able to articulate what the experiment should achieve.				
2. state the relationship of variables ability	Be able to distinguish between independent variables, dependent variables and various dependent variables affecting the results of an experiment, and be able to set up settings to ensure the singularity of the variables and find ways to				

variable/indicator	Define	Expert			Sug gest ion
		+1	0	-1	
	eliminate the influence of extraneous variables on the results of an experiment.				
3. describe the experimental procedure ability	Be able to write the experimental ideas that have been formed into logical, practical and concrete experimental steps, consider the problems that should be noted in the experiment, to ensure that the operation is scientific and rigorous.				
4. express the expected results of an experiment ability	Be able to predict experimental phenomena that may occur and explain the conclusions indicated by the phenomena, or apply experimental principles to explain the causes of different phenomena.				

Part 2 Experimental Design Ability Assessment

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
1. specify the purpose of an experiment ability					
1.	Koala balsam pear fruit exists in the free state and combined state two categories of aromatic substances. Most of the combined state of aroma substances in the form of glycosides, no aroma, but in β-D-glucosidase can be decomposed under the action of the release of volatile free state of aroma substances. If the above transformation process is rapid during the storage of pears, it will lead to the loss of some of the aroma components, affecting the flavors and quality of the fruit. Researchers have carried out related experiments (the results are shown in the figure below), please analyses the answer:  What is the purpose of this experiment?				
2.	Newly harvested rice is cooked with an attractive aroma, but unscrupulous traders can also use rice polishing and whitening, oiled to				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
	deceive consumers. Hydrogen peroxidase activity is significantly higher in new rice than in old rice. Hydrogen peroxidase in the plant body in the presence of hydrogen peroxide (H_20_2) can be some phenolic compounds such as guaiacol oxidized into reddish-brown substances, simply expressed: guaiacol a reddish-brown substance, the color of the depth and enzyme activity is positively correlated. Now the food hygiene and quality inspectors have designed a simple experiment to test whether the rice soup is new rice. What is the purpose of this experiment? The purpose of this experiment:				
2. state the relationship of variables ability					
3.	A biology interest group is carrying out a study on "the effect of different concentrations of growth hormone analogue on seed germination and seedling growth", and the teacher has prepared a concentrated solution of growth hormone analogue and radish seeds for them. If you are one of them, please answer: 2.1To determine the effect of growth hormone analogue on seed germination and seedling growth, you can use the measurement indexes___ ___ ___ ___, ___ ___ ___and so on.				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
	2.2 How would you set up a control group when doing this experiment?				
4.	4.It has been found that UV light inhibits plant growth, probably because it increases the activity of indoleacetic acid oxidase in plants. Thus, it catalyzes the oxidation of growth hormone to 3-methylene oxoindole and loses its role in promoting cell elongation. Now the teacher provides a number of wheat seedlings with the same growth condition and healthy as experimental materials, and asks groups of students to carry out experiments in order to investigate the UV inhibition of plant growth related to the oxidation of growth hormone. If you are one of them, please answer: 4.1 The independent variable in this experiment is ....., the dependent variable is..... 4.2 How would you set up a control group when doing this experiment?				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
3. describe the experimental procedure ability					
5.	The seeds of a plant are known to be affected by water, temperature and oxygen, but it is not known whether their germination is related to light. To investigate the effect of the presence or absence of light on the germination of this seed, design the methodological steps of the experiment based on the materials and supplies given: Materials and supplies: a sufficient number of petri dishes lined with filter paper, sterile water, surface-sterilized seeds, etc. The methodological steps of the experiment:				
6.	Glucagon has the same physiological effect on mice and humans. In order to verify that "glucagon has the physiological effect of elevating blood glucose", please design an experiment using mice as the test object. (1) Experimental materials an equipment:2 normal mice, saline, glucagon solution prepared with saline at the appropriate concentration, Ban's glucose characterization reagent, syringes, test tubes, beakers and so on. (2) Experimental steps:(Experimental tips:				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
	use intraperitoneal injection to give the drug, the dose of the drug is not required for the experimental design; 1 hour after the administration of the drug, use a syringe to take urine by puncture at the bladder of the mice)				
4. express the expected results of an experiment ability					
7.	A student wondered whether temperature could affect the activity of thyroxine by associating it with the ability of temperature to affect enzyme activity. To explore this question, he conducted an experiment. Predict the experimental phenomena and conclusions based on the experimental steps given. Experimental steps. (1) Take three identical clean glass cylinders, numbered, and fill each with equal amount of river water. (2) Take 15 tadpoles with the same developmental status, divide them into three equal parts, and put them into glass tanks No. 1, 2 and 3 respectively, and cultivate the three glass tanks under the same suitable external conditions. (3) Every day, equal amounts of normal feed, feed mixed with thyroid preparation, and feed mixed with thyroid preparation treated with				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
	60℃ warm water for 1 hour were put into No.1, 2 and 3 glass tanks at the same time. (4) Compare the development of tadpoles after a few days. Predict the experimental phenomena and conclusions:				
8.	In order to verify the physiological role of thyroid hormone, try to the rat's oxygen consumption and activity as an indicator of observation, please give you according to the experimental materials and appliances, experimental methods and steps, predict the results of the experiment, and make an analysis. Materials and appliances: two groups of male adult rats of the same age and similar weight, thyroid hormone solution, distilled water, gavage, oxygen consumption measurement device, small animal activity meter, etc. (The route of administration was daily gavage, the dose administered and the instrumentation, not required for the exam, was constant room temperature.). Methods and steps: (1) Two groups of male adult rats were labeled as Group A and Group B. Oxygen consumption and activity were measured and				

No.	Assessment Program	Expert			suggestion
		+1	0	-1	
	recorded with the given apparatus, respectively. (2) Group A rats were given thyroid hormone solution by gavage and group B rats were given equal amount of distilled water by gavage daily for a certain period of time. (3) The oxygen consumption and activity of rats in groups A and B were measured and recorded. Predict the experimental phenomena and conclusions:				

Assessment form for Validity of lesson plan I-IV

Research Title: Using 5E inquiry-based teaching to improve experimental design ability for middle school students

Research Objectives:

1. To using 5E inquiry-based teaching to improve the experimental design ability for middle school students

2. To compare students' experimental design ability, before and after the implementation is 5E inquiry-based teaching.

Directions:

Directions:

Please assess the congruence between components of lesson plan based on 5E inquiry-based teaching by putting ✓ in the box according to the following criteria.

Rating is +1. There is an opinion that "consistent to relevant."

Rating is 0. There is an opinion that "Not sure it consistent to relevant."

Rating is -1. There is an opinion that "Inconsistent with relevant."

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
1	Learning objectives sort the contents from easy to difficult.				
2	5E inquiry-based teaching encourages students to work in teams and solve problems rationally.				
3	Determining content suitable for the age of students.				
4	Organizing activities suitable for learning objectives.				
5	5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.				
6	Learning activities are linked from basic knowledge to ask questions, express their real				

No.	Questions	Assessment Results			Suggestions
		+1	0	- 1	
	ideas and effective discussion.				
7	The using instructional media are suitable for learning activities.				
8	The duration of the activity is appropriate for improving the experimental design ability of middle school students.				
9	Measurement and evaluation are suitable for learning activities to develop real ability.				
1 0	Assessment criteria are appropriate for subjective learning.				

Sign.....Assessor

(.....)

Date...../...../.....

Appendix D

The Results of the Quality Analysis of Research Instruments

Table 1 Analysis of the Index of Coherence (IOC) of lesson plans to improve experimental design ability of middle school students with 5E Inquiry Based teaching

Evaluation checklist	experts			Sum of scores	IOC value
	1	2	3		
Lesson Plan I: Structure and function of cell membrane					
1. Learning objectives sort the contents from easy to difficult.	+1	+1	+1	3	1
2. 5E inquiry-based teaching encourages students to work in teams and solve problems rationally.	+1	+1	+1	3	1
3. Determining content suitable for the age of students.	+1	+1	+1	3	1
4. Organizing activities suitable for learning objectives.	+1	0	+1	2	0.67
5. 5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.	+1	+1	+1	3	1
6. Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.	+1	+1	+1	3	1
7. The using instructional media are suitable for learning activities.	+1	+1	0	2	0.67
8. The duration of the activity is appropriate for improving the experimental design ability of middle school students.	+1	+1	+1	3	1
9. Measurement and evaluation are suitable for learning activities to develop real ability.	+1	+1	+1	3	1
10. Assessment criteria are appropriate for subjective learning.	+1	+1	+1	3	1

Table 1 (continue)

Evaluation checklist	experts			Sum of scores	IOC value
	1	2	3		
Lesson Plan II: Active transportation and endocytosis, exocytosis					
1. Learning objectives sort the contents from easy to difficult.	+1	+1	+1	3	1
2. 5E inquiry-based teaching encourages students to work in teams and solve problems rationally.	+1	+1	+1	3	1
3. Determining content suitable for the age of students.	+1	+1	+1	3	1
4. Organizing activities suitable for learning objectives.	+1	0	+1	2	0.67
5. 5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.	+1	+1	+1	3	1
6. Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.	+1	+1	+1	3	1
7. The using instructional media are suitable for learning activities.	+1	+1	0	2	0.67
8. The duration of the activity is appropriate for improving the experimental design ability of middle school students.	+1	+1	+1	3	1
9. Measurement and evaluation are suitable for learning activities to develop real ability.	+1	+1	+1	3	1
10. Assessment criteria are appropriate for subjective learning.	+1	+1	+1	3	1

Table 1 (continue)

Evaluation checklist	experts			Sum of scores	IOC value
	1	2	3		
Lesson Plan III: Enzymes that reduce the activation energy of chemical reactions					
1. Learning objectives sort the contents from easy to difficult.	+1	+1	+1	3	1
2. 5E inquiry-based teaching encourages students to work in teams and solve problems rationally.	+1	+1	+1	3	1
3. Determining content suitable for the age of students.	+1	+1	+1	3	1
4. Organizing activities suitable for learning objectives.	+1	0	+1	2	0.67
5. 5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.	+1	+1	+1	3	1
6. Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.	+1	+1	+1	3	1
7. The using instructional media are suitable for learning activities.	+1	+1	0	2	0.67
8. The duration of the activity is appropriate for improving the experimental design ability of middle school students.	+1	+1	+1	3	1
9. Measurement and evaluation are suitable for learning activities to develop real ability.	+1	+1	+1	3	1
10. Assessment criteria are appropriate for subjective learning.	+1	+1	+1	3	1

Table 1 (continue)

Evaluation checklist	experts			Sum of scores	IOC value
	1	2	3		
Lesson Plan IV: Photosynthesis and energy conversion					
1. Learning objectives sort the contents from easy to difficult.	+1	+1	+1	3	1
2. 5E inquiry-based teaching encourages students to work in teams and solve problems rationally.	+1	+1	+1	3	1
3. Determining content suitable for the age of students.	+1	+1	+1	3	1
4. Organizing activities suitable for learning objectives.	+1	0	+1	2	0.67
5. 5E inquiry-based teaching activities actually motivate students to learn and creative problem solving.	+1	+1	+1	3	1
6. Learning activities are linked from basic knowledge to ask questions, express their real ideas and effective discussion.	+1	+1	+1	3	1
7. The using instructional media are suitable for learning activities.	+1	+1	0	2	0.67
8. The duration of the activity is appropriate for improving the experimental design ability of middle school students.	+1	+1	+1	3	1
9. Measurement and evaluation are suitable for learning activities to develop real ability.	+1	+1	+1	3	1
10. Assessment criteria are appropriate for subjective learning.	+1	+1	+1	3	1

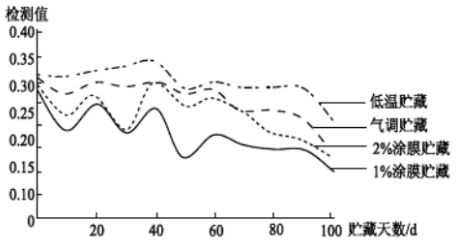
Table 2 Consistency Index (IOC) Analysis of Experiment Design Ability with survey variables

Evaluation checklist	Comment score			Sum of scores	IOC value
	1	2	3		
1. specify the purpose of an experiment ability Be able to articulate what the experiment should achieve.	+1	+1	+1	3	1
2. state the relationship of variables ability Be able to distinguish between independent variables, dependent variables and various dependent variables affecting the results of an experiment, and be able to set up settings to ensure the singularity of the variables and find ways to eliminate the influence of extraneous variables on the results of an experiment.	+1	+1	+1	3	1
3. describe the experimental procedure ability Be able to write the experimental ideas that have been formed into logical, practical and concrete experimental steps, consider the problems that should be noted in the experiment, to ensure that the operation is scientific and rigorous.	+1	+1	+1	3	1

Table 2 (continue)

Evaluation checklist	Comment score			Sum of scores	IOC value
	1	2	3		
4. express the expected results of an experiment ability Be able to predict experimental phenomena that may occur and explain the conclusions indicated by the phenomena, or apply experimental principles to explain the causes of different phenomena.	+1	+1	+1	3	1

Table 3 Consistency Index (IOC) Analysis of Experimental Design Ability assessment of Middle School Students

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
1.	Koala balsam pear fruit exists in the free state and combined state two categories of aromatic substances. Most of the combined state of aroma substances in the form of glycosides, no aroma, but in β-D-glucosidase can be decomposed under the action of the release of volatile free state of aroma substances. If the above transformation process is rapid during the storage of pears, it will lead to the loss of some of the aroma components, affecting the flavors and quality of the fruit. Researchers have carried out related experiments (the results are shown in the figure below), please analyses the answer: What is the purpose of this experiment? 	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
2.	Newly harvested rice is cooked with an attractive aroma, but unscrupulous traders can also use rice polishing and whitening, oiled to deceive consumers. Hydrogen peroxidase activity is significantly higher in new rice than in old rice. Hydrogen peroxidase in the plant body in the presence of hydrogen peroxide (H_20_2) can be some phenolic compounds such as guaiacol oxidized into reddish-brown substances, simply expressed: guaiacol a reddish-brown substance, the color of the depth and enzyme activity is positively correlated. Now the food hygiene and quality inspectors have designed a simple experiment to test whether the rice soup is new rice. If you participate in this experiment, what do you think the experiment should achieve?	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
3.	A biology interest group is carrying out a study on "the effect of different concentrations of growth hormone analogue on seed germination and seedling growth", and the teacher has prepared a concentrated solution of growth hormone analogue and radish seeds for them. If you are one of them, please answer: 3.1To determine the effect of growth hormone analogue on seed germination and seedling growth, you can use the measurement indexes....., ...and so on. 3.2 How would you set up a control group when doing this experiment?	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
4.	It has been found that UV light inhibits plant growth, probably because it increases the activity of indoleacetic acid oxidase in plants. Thus, it catalyzes the oxidation of growth hormone to 3-methylene oxindole and loses its role in promoting cell elongation. Now the teacher provides a number of wheat seedlings of the same growth condition and healthy as experimental materials to investigate the UV inhibition of plant growth related to the oxidation of growth hormone. Based on the experimental information provided, determine what are the independent and dependent variables in this experiment? And briefly explain how you would set up the control group?	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
5.	The seeds of a plant are known to be affected by water, temperature and oxygen, but it is not known whether their germination is related to light. To investigate the effect of the presence or absence of light on the germination of this seed, design the methodological steps of the experiment based on the materials and supplies given: Materials and supplies: a sufficient number of petri dishes lined with filter paper, sterile water, surface-sterilized seeds, etc. The methodological steps of the experiment:	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
6.	Glucagon has the same physiological effect on mice and humans. In order to verify that "glucagon has the physiological effect of elevating blood glucose", please design an experiment using mice as the test object. (1) Experimental materials and equipment:2 normal mice, saline, glucagon solution prepared with saline at the appropriate concentration, Ban's glucose characterization reagent, syringes, test tubes, beakers and so on. (2) Experimental steps: (Experimental tips: use intraperitoneal injection to give the drug, the dose of the drug is not required for the experimental design; 1 hour after the administration of the drug, use a syringe to take urine by puncture at the bladder of the mice)	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
7.	A student wondered whether temperature could affect the activity of thyroxine by associating it with the ability of temperature to affect enzyme activity. To explore this question, he conducted an experiment. Experimental steps: (1) Take three identical clean glass cylinders, numbered, and fill each with equal amount of river water. (2) Take 15 tadpoles with the same developmental status, divide them into three equal parts, and put them into glass tanks No. 1, 2 and 3 respectively, and cultivate the three glass tanks under the same suitable external conditions. (3) Every day, equal amounts of normal feed, feed mixed with thyroid preparation, and feed mixed with thyroid preparation treated with 60℃ warm waters for 1 hour were put into No.1, 2 and 3 glass tanks at the same time. (4) Compare the development of tadpoles after a few days.	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
	Please predict and analyze the experimental phenomena and conclusions based on the experimental steps given above.					
8.	In order to verify the physiological role of thyroid hormone, try to the rat's oxygen consumption and activity as an indicator of observation, please give you according to the experimental materials and appliances, experimental methods and steps, predict the results of the experiment, and make an analysis. Materials and appliances: two groups of male adult rats of the same age and similar weight, thyroid hormone solution, distilled water, gavage, oxygen consumption measurement device, small animal activity meter, etc. (Experimental hints: the route of administration was daily gavage, the dose administered and the instrumentation, not required for the exam, was constant room temperature.). Methods and steps:	+1	+1	+1	3	1

No.	Assessment Program	Comment score			Sum of scores	IOC value
		1	2	3		
	(1) Two groups of male adult rats were labeled as Group A and Group B. Oxygen consumption and activity were measured and recorded with the given apparatus, respectively. (2) Group A rats were given thyroid hormone solution by gavage and group B rats were given equal amount of distilled water by gavage daily for a certain period of time. (3) The oxygen consumption and activity of rats in groups A and B were measured and recorded.					

Table 4 Comparison of academic performance before and after using 5E Inquiry-Based Teaching to improve middle school students' Experimental Design Ability instruction

Student id	Pre-School score (Pre-Test)	After school score (Post-Test)	Difference between points(D)
1	21	22	1
2	22	24	2
3	15	20	5
4	18	19	1
5	18	19	1
6	11	16	5
7	17	18	1
8	20	21	1
9	12	17	5
10	13	18	5
11	21	22	1
12	11	15	4
13	21	24	3
14	13	17	4
15	17	21	4
16	10	13	3
17	12	18	6
18	18	21	3
19	15	19	4
20	11	14	3
21	13	18	5
22	13	19	6
23	17	20	3
24	13	17	4
25	11	14	3
26	20	22	2
27	20	24	4
28	21	24	3
29	21	22	1
30	16	20	4
$\bar{X}$	16.03	19.27	3.24

Appendix E

Certificate of English

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Appendix F

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17 October 2023

Title: Paper Acceptance

Dear Yin Hua

On behalf of the Organizing Committee and Peer Review Committee, we are pleased that your paper titled,

"Using 5E Inquiry based teaching to improve experimental design ability for middle school students"

submitted for presentation at the 18th National and the 8th International Sripatum University Conference (SPUCON2023) on Research and Innovations to Sustainable Development, held on 27 October 2023, is formally accepted for inclusion in the conference program.

The conference program is shaping up to reflect a wonderful event. We hope that you will be able to fully participate in the conference and take advantages of all the benefits that this conference offer participants and attendees. Besides, your presented paper will be published in the on-line proceedings which will be available at http://spucon.spu.ac.th

We are looking forward to meeting you.

Sincerely yours,

(Assoc. Prof. Subin Yurarach, Ph.D.)
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Using 5E Inquiry based teaching to improve experimental design ability for middle school students

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ABSTRACT

The objectives of this study were 1) to improve middle school students' experimental design ability using 5E inquiry-based instruction and 2) to compare students' experimental design ability before and after the implementation of 5E inquiry-based instruction. The simple group of this study consisted of 30 samples from a middle school in Weifang, China. The research tools included 1) lesson plans and 2) experimental design ability test. The test questions were designed to test four sub-variables in the dependent variable, including the test questions were designed to test three sub-variables in the dependent variable, including the ability to specify the purpose of an experiment, the ability to state the relationship of variables, the ability to describe the experimental procedure, the ability to express the expected results of an experiment. The data were analyzed by mean ($\overline{X}$), standard deviation (S.D.) and Paired Sample t-test for dependent samples. The results revealed the followings: 1. Through the use of 5E Inquiry based teaching and observation of students' learning behaviors, it is found that students' experimental design ability has been improved. The experimental design ability competence scores of the secondary school students before and after using 5E Inquiry based instruction averaged 16.03 on the pre-test and 19.27 on the post-study test, with a mean difference of 3.24 points. The post-learning scores were found to be higher than the pre-learning scores.2. Using 5E Inquiry based teaching, the experimental design ability of middle school students after class is significantly higher than before class, with statistical significance at the level .01. the experimental design ability after class is higher than before class. P<.01indicates statistical significance at the 0.01 level. By implementing the experimental design ability on students, their experimental design ability after class is significantly higher than that before class. This is consistent with the research hypothesis.

KEYWORDS: 5E Inquiry based Teaching, Experimental Design Ability, middle school student

1. Introduction

In 2010, China's Ministry of Education issued the Outline of the National Medium- and Long-Term Educational Reform and Development Plan (2010-2020), which pointed out the need to reform teaching methods and content, advocate participatory and inquiry-based teaching, focus on giving full play to the subjective

initiative of students' learning, and vigorously promote the all-round development of human beings. In response to the call of the new era, in 2020, the Ministry of Education promulgated the General High School Biology Curriculum Standards (2017 Edition Revised in 2020), in the implementation of the recommendations, it is clearly pointed out that experimental teaching is an important support for students to achieve the core literacy of the discipline of biology, and it is necessary to strengthen and improve the experimental teaching of biology. The experimental design is the key link of experimental teaching.

Currently, the cultivation of experimental design skills in high school is not satisfactory.The lack of experimental courses has always been a problem in our high school biology teaching (Mi & Hyun, 2013). High school biology teaching often does not emphasize laboratory courses and lacks relevant laboratory equipment. Some high schools do not conduct laboratory courses or have fewer hours of laboratory courses, and the vividness and effectiveness of biology teaching will be greatly reduced.

The application of traditional teaching mode in high school laboratory teaching has certain limitations. At present, in our classroom teaching process, teachers' classroom questions and dialogues are put forward to solve problems, and do not have in-depth excavation of the problem, not to mention in-depth study of the nature of the problem, still staying in the traditional questioning teaching methods. cannot stimulate students to think about problems in class and guide students to understand the classroom content.(Nina & Cigdem, 2016)

5E Inquiry based teaching provides a path for high school laboratory teaching. Ni (2022) pointed out that the 5E teaching model is an important educational model in the field of science education, and its purpose is to help students realize conceptual transformation and scientific conceptual construction. This teaching model has been applied to the overall curriculum design of Biological Science Curriculum Study (Abbreviation BSCS) since the late 1980s and has been highly recognized. Applying the five components of 5E Inquiry based teaching to high school biology teaching is conducive to improving students' learning motivation and experimental design ability.

5E Inquiry based teaching has a positive impact on senior high school students' further improvement of biological scientific thinking, can mobilize students' enthusiasm for classroom learning to a certain extent, effectively promote the process of active interaction between teachers and students, and improve senior high school students' biological scientific thinking, so it is worth applying in senior high school biology classroom teaching or classroom learning to a certain extent, effectively promote the process of active interaction between teachers and students, and improve senior high school students' biological scientific thinking, so it is worth applying in senior high school biology classroom teaching.

2. Research Objective

(1) To using 5E Inquiry based teaching to improve the experimental design ability for middle school students.

(2) To compare students' experimental design ability, before and after the implementation is 5E Inquiry based teaching.

3. Literature Review

3.1 Theory, Concept and Related Research

Using 5E Inquiry based teaching to improve experimental design ability for middle school students, the following literatures were studied.

5E Inquiry based teaching

In 1989, BSCS revised and improved the Atkin-Karplus learning loop model, and proposed a 5E teaching model based on constructionist theory and concept transformation theory. This model includes five links, namely, attraction, exploration, interpretation, migration and evaluation. According to Ong et al. (2018), the 5E teaching model consists of the following five stages: participation, exploration, explanation, refinement, and evaluation. each stage has a specific pedagogical function that contributes to the coherence of the teacher's teaching and the learners' formation of scientific and technological knowledge.Zhu (2022) pointed out that the 5E Inquiry based teaching model consists of five parts: introduction, exploration, interpretation, transfer and evaluation. It is student-centered and flexible. It can improve students' enthusiasm for learning, help students understand important concepts and are of great benefit to junior high school biology teachers to cultivate students' structure and function view.

5E Inquiry based teaching is an important model of participatory, inquiry-based teaching and learning that is student-centered and consists of five components: engagement, exploration, expansion, elaboration and Evaluation.

Experimental design ability

Dasgupta, Anderson & Pelaez (2014) believed that the competencies required for a competent experimental design include identifying the problem; generating the hypothesis; planning the experimental procedure, including treatment, control, and outcome variables; and interpreting the study results to make inferences. Du (2019) pointed out in the strategy of improving students' experimental design ability that experimental design refers to the planning of the whole process of the experiment, including putting forward questions, guessing hypotheses, designing experiments and customizing plans, conducting experiments and collecting evidence, analyzing and demonstrating, evaluating, communicating and cooperating, etc.

Experimental design ability is an important part of scientific research, which covers a series of links from understanding the purpose of the experiment, determining the experimental variables to choosing an appropriate experimental design, developing detailed experimental steps, choosing appropriate statistical analysis methods, interpreting the results of the experiment to writing the experimental report.

Middle school program

China's Ministry of Education mentions in the Compulsory Education Biology Curriculum Standards (2022) that general high schools offer national courses in language, mathematics, foreign languages, ideology and politics, history, geography, physics, chemistry, biology, technology (including information technology and general technology), art (or music and fine arts), physical education and health subjects, and comprehensive practical activities and labor, as well as school-based courses. China's Ministry of Education's "In the General High School Biology Curriculum Standards (2017 Edition, 2020 Revision)" (2020) mentions that the General High School Curriculum Program stipulates that the high school biology curriculum offers compulsory, optional compulsory and elective courses.

3.2 Research Framework

Outline of the National Medium- and Long-Term Educational Reform and Development Plan (Ministry of Education of China, 2010) points out that we should adhere to the principles of moral education first and competence first, reform the teaching methods and contents, advocate participatory and inquiry teaching, and focus on giving full play to the subjective initiative of students in learning. Taking the secondary school biology curriculum as the research carrier, this study explores in-depth the mode and method of cultivating students' experimental design ability in teaching and learning, and designs the teaching content, prepares the teaching plan, and designs the teaching process based on the enhancement of students' experimental design ability according to the 5 steps of 5E inquiry-based teaching, which is used to improve the experimental design ability of secondary school students. The conceptual framework of the study is as follows:

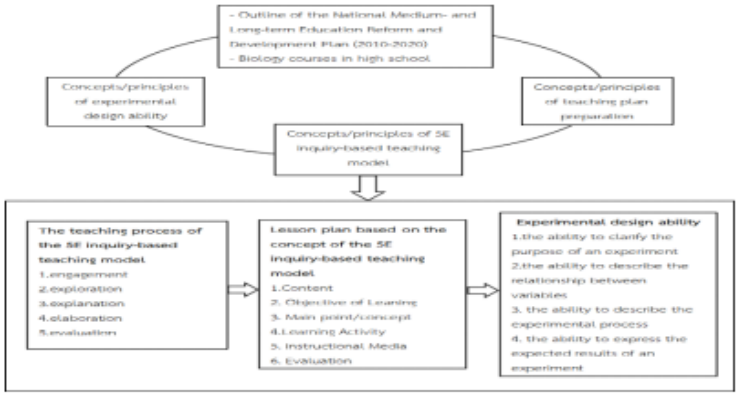

Figure 1 Research Framework

3.3 Research Hypotheses

After the implementation based on 5E Inquiry based teaching, the students' experimental design ability has been improved explicitly.

4. Research Methodology

The experimental purpose of this study was using 5E Inquiry based teaching to improve the experimental design ability for middle school students. The research using experimental research methodology ~~have~~ has the following procedures.

4.1 Research Design

The research "using 5E Inquiry based teaching to improve experimental design ability for middle school students " aims to improve experimental design ability of middle school students by 5E Inquiry based teaching, and compare the experimental design ability of students before and after class when using 5E Inquiry based teaching. Before and after teaching test: This research is experimental research. One Group Pretest – Posttest Design was used with the following experimental design:

Table 1 Experimental design

Group	Pretest	Experimental	Posttest
E	T_1	X	T_2

4.2 Population and Sample

Population

There are 120 students in the first grade of the senior middle school of a middle school in Weifang, China,, divided into 4 classes with 30 students in each class., in the first semester of the 2023 academic year.

The Sample Group

According to the principle of randomization, 1 class out of 4 classes was taken as the class sample. Through random cluster sampling, 30 students from Class 2, Grade 1 of high school in the first semester of the 2023 academic year in a middle school in Weifang were selected as the sample.

4.3 Research Instrument

Using 5E Inquiry based teaching to improve the experimental design ability for middle school students. The research Instruments is as follows:

1.Lesson plan according to the 5E Inquiry based teaching: The teaching content was divided into four parts, each part corresponding to a teaching plan, a total of four teaching plans, respectively, in accordance with the teaching steps of 5E inquiry-based teaching.

2.Experimental design ability Test: In this research, the experimental design ability was divided into four sub-competencies, including the ability to specify the purpose of the experiment, the ability to explain the relationship between variables, the ability to describe the experimental process, and the ability to express the expected results of the experiment. The researcher designed his own test questions for these four sub-competencies and used them to test students' experimental design ability after passing the assessment by experts.

4.4 Data Collection

The data were collected as follows:

1. Pre-experiment phase: 1) Organize an explanation meeting before the experiment to help students understand the evaluation methods of learning objectives, as well as the benefits of participating in ability tests and learning activities during the experiment. 2) Conduct a pre-test for sophomore medical students in the first semester of the 2023 academic year, with a total of 30 students as a sample group, and check the score records for data analysis.

2. Experimental phase: The experimental stage is the stage where the sample group learns using the activity plan developed by the researchers. The stage of learning in the activity plan. The teaching time is a total of 12 hours, excluding pre-test and post-test time.

3. Post-experiment phase: After teaching all the content, a group of sampled students will be tested for their abilities. After learning, conduct a test (post-test), and then check and score according to the scoring standards set by the researchers. After the scores have been reviewed and merged, further data analysis will be submitted.

4.5 Data Analysis

In this study, a lesson plan was developed according to the 5 steps of 5E Inquiry based teaching and 30 middle school students from a middle school in Weifang, China was taught according to the lesson plan to obtain the pre-test scores and post-test scores of experimental design ability. These data were coded, counted, and statistically processed using t-test for mean, standard deviation, and significant difference. The data were statistically analyzed using paired samples t-test analysis. It compares whether the means of two independent groups or variables are different. This was used to compare the level of students' experimental design ability before and after using the 5E Inquiry based teaching.

5. Research Findings

This study concludes that the strategy of teaching experimental design ability based on 5E Inquiry based teaching is reasonable and effective through the experimental design and the following conclusions are drawn:

Table 2 Experimental design ability score between before and after learning

n= 30

Experimental design ability	Full	Pre-test		Post-test		D
	Scores (24)	$\overline{X}$	Percentage (100%)	$\overline{X}$	Percentage (100%)	
1.the ability to specify the purpose of an experiment	6	4.10	68.33	5.03	83.83	0.93
2.the ability to state the relationship of variables	6	4.03	67.17	4.83	80.50	0.80
3.the ability to describe the experimental procedure	6	4.17	69.5	4.73	78.83	0.56

4.the ability to express the expected results of an experiment	6	3.73	62.17	4.67	77.83	0.94
total		16.03	66.79	19.27	80.29	3.24

From Table 2, it can be seen that changes in the four sub-competencies of the experimental design competencies of middle school students using 5E inquiry-based instruction:1) the ability to clarify the purpose of the experiment : the average score before learning was 4.10, and the average score after learning was 5.03, with an average difference of 0.93; 2) the ability to explain the relationship of variables : the average score before learning was 4.03, and the average score after learning was 4.83, with an average difference of 0.80; 3) the ability to describe the experimental process : the average score before learning was 4.17 points before learning and 4.73 points after learning, with an average difference of 0.56 points; 4) the ability to express the expected results of the experiment: the average score before learning was 3.73 points, and the average score after learning was 4.67 points, with an average difference of 0.94 points, and the scores of all the items after learning were higher than those before learning. Therefore, using 5E inquiry-based teaching can improve junior high school students' experimental design ability and achieve the research objectives.

Table 3 the comparison of experimental design ability score between before and after learning.

		N	Full Point	$\overline{X}$	SD.	T	P
Total score	Pre-test	30	24	16.03	3.89	11.134	0.001**
	After-test	30	24	19.27	3.08		

**Statistically significant at level. 01($p < .01$)

From Table 3, it can be seen that the scores of students' experimental design ability after learning are higher than before learning, with statistical significance at the 0.01 level; The students' ability to design experiments using the 5E Inquiry based teaching scored an average of 16.03 points before learning and 19.27 points after learning, with an average difference of 3.24 points. The results showed that after using 5E Inquiry based teaching, the students' experimental design ability increased compared to before. The results are statistically significant.

6. Discussion

(1)Using the 5E Inquiry based teaching to improve students' experimental design ability. Researchers have studied many relevant literature and research on Inquiry based teaching, and have summarized it into five steps for developing lesson plans based on the 5E Inquiry based teaching methods of middle school students. Data analysis involves three experts evaluating the quality of lesson plans based on exploratory teaching methods, and the results are presented by experts on the quality of lesson plans. Overall, the suitability of research objectives is the most appropriate. This is because the developed learning plan is consistent with the concept of 5E Inquiry based teaching, and the developed curriculum plan includes key elements of the curriculum plan.

Learn complete and relevant content clearly and comprehensively. The established activities emphasize the practical learning, practical thinking, and practical abilities of learners in experimental design. In terms of measurement and evaluation, it is determined to be an assessment based on actual situations, measured according to learning objectives, and determined whether the workpiece and workload are suitable based on learning objectives, which is consistent with the research of Qiu (2022) and Zhang (2022). They pointed out that combining the 5E Inquiry based teaching model with the requirements of practical activities in the teaching process in the basic concept of the new curriculum standard; we should carry out practical research on the biological activity class, and explore the relevance between the activity class and the 5E teaching model. The students' core literacy level has been greatly improved through the learning in the high school biological activity class under the 5E teaching mode. The results of student self-evaluation and mutual evaluation show that students' interest in biology learning is significantly improved through the learning of biological activity class under the 5E teaching mode. Through practical teaching case studies of the 5E Inquiry based teaching, the full application of the 5E Inquiry based teaching in practical teaching has achieved student learning results. In addition, Singh (2020) emphasized that exploratory learning is another criterion for effective knowledge transfer. She serrated out that although people might expect different things/practices when they referred to inquiry-based learning, there were decisive Characteristics that required being nearby, including an integrated prospectus across regulation, a problem-based teaching room, and deliberation to skills enlargement. The research results of Luan (2022) indicate that the 5E Inquiry based teaching reflects students' subjectivity in the teaching process. The teaching process of exploratory teaching method generally includes five steps. With the continuous development of the new curriculum reform, the theoretical and practical research of the teaching model has also shown a trend of prosperity. In order to meet the requirements of the new era for talent cultivation, the inquiry teaching model advocating active independent learning, cooperative learning and inquiry learning has been placed in an important position. There is further elaboration on the development and implementation of 5E Inquiry based teaching in different literature.

(2)Comparison of students' experimental design abilities before and after learning using 5E Inquiry based teaching. The results showed that the average score before learning was 16.03 points, and the average score after learning was 19.27 points, with an average difference of 3.24 points. The results showed that the experimental design ability of 30 students after learning was higher than that before learning, with statistical significance at the 0.01 level, which is consistent with the hypothesis. which is consistent with the hypothesis. 5E Inquiry based teaching lies in its student-cantered approach, which stimulates students' interest through practical experimental design skills, enhances each student's participation, and promotes the development of their comprehensive abilities. This is consistent with Du (2019). He pointed out in the strategy of improving students' experimental design ability that experimental design refers to the planning of the whole process of the experiment, including putting forward questions, guessing hypotheses, designing experiments and customizing plans, conducting experiments and collecting evidence, analyzing and demonstrating, evaluating, communicating and cooperating,

etc. The 5E Inquiry based teaching is a teaching method that focuses on students' independent exploration, which helps to cultivate students' experimental design ability to the maximum extent possible. Through the 5E Inquiry based teaching, students' experimental design ability has been significantly improved. The results indicate that the 5E Inquiry based teaching has a positive impact on students' success, and selecting teaching methods that are suitable for students' personal interests and abilities is very important.

7. Suggestion

(1) In this study, only 5E inquiry-based teaching was used to improve students' experimental design ability, and other teaching methods or teaching modes can be further considered to improve students' experimental design ability, or a combination of teaching methods or teaching modes can be combined to improve students' experimental design ability, such as: flipped classroom, group cooperative learning, PBL teaching method, etc.

(2) This study improved students' experimental design ability through 5E inquiry-based teaching, and it has been verified to be effective, but students' abilities are also multi-faceted, so we can consider using 5E inquiry-based teaching to improve students' abilities in other areas, such as critical thinking ability, problem solving ability, innovative thinking ability, etc., which will help students' comprehensive ability development.

(3)This study uses the secondary school biology curriculum as a vehicle to use 5E inquiry-based teaching to improve students' experimental design skills, and can consider applying the 5E inquiry-based teaching method to other secondary school curricula, or even to a wider range of disciplines, so as to develop a unique teaching style.

8. Acknowledgement

I would like to thank my supervisors, Assistant Professor Dr. Phatchareephom BangKheow and Dr. Phenpom Thongkamsuk, for their dedicated teaching and selfless assistance in the selection of the thesis topic, determination of the experimental protocols, theoretical analyses, data processing, thesis writing, and finalization of the thesis; and the three experts who evaluated the quality of the research instrumentation. The quality of the research instrument was evaluated by three experts. Finally, I would like to thank my family and other teachers for their help in my study and life, and the other members of the group for their help during the whole thesis process.

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