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Development of PjBL Module for Preschool Science Teachers in China

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Abstract. This research aims to design and develop project-based learning (PjBL) modules suitable for early science education in China to meet the current challenges in science education. Guided by constructivist theory and the 4-D model, this research focuses on the development and implementation of project-based learning (PjBL) modules for early science in Chinese preschools. The research aimed to develop children's critical thinking and cooperative skills through cooperative and inquiry-based activities. Drawing on the developmental theories of Piaget and Vygotsky, the research combined hands-on projects and cooperative learning to create a systematic framework for project-based early science education tailored to children.The 4-D model provided a systematic approach that included definition, design, development, and dissemination phases. Pilot research involving six children demonstrated the effectiveness of the module in promoting critical thinking and cooperative skills. Quantitative and qualitative analyses highlighted significant limitations in critical thinking, problem solving, communication and teamwork. Future exploration of the module's effectiveness in other disciplines and its impact on teacher professional development is recommended. This research contributes to the growing PjBL knowledge base and provides practical insights for enhancing preschool education through innovative teaching strategies.

Keywords: Project-based learning (PjBL), Preschool science education, Critical thinking, Cooperative skills, 4-D model.

1. Introduction

This research provides a detailed introduction to the design and development process of the early science Project-Based Learning (PjBL) module in Chinese preschool education. This research is based on constructivist theory, which emphasizes the positive role of learners in constructing knowledge through meaningful interactions with the environment. This research incorporates Piaget's stages of cognitive development and Vygotsky's theory of social development. It illustrates how PjBL promotes the development of critical thinking and cooperative skills in children [1]. By fostering critical thinking and cooperative skills, PjBL provides a framework for teaching early science that is tailored to the developmental needs of young learners [1]. PjBL has been widely applied in modern education, especially for preschool children, as it is considered an effective teaching method. Implementing project-based learning can stimulate children's interest in learning, help them discover and solve problems in real-world contexts, and achieve success through teamwork [2].

The PjBL module plays an essential role in fostering critical thinking and Cooperative skills in preschool children. Critical thinking is the ability of children to identify problems, analyze, reason, and solve them [3]. This skill is crucial in science education and has a lasting impact on children's future learning and life. Through PjBL projects, children can raise questions, design experiments, collect, and analyze data, thereby systematically enhancing their critical thinking abilities [3].

Cooperative skills are also extremely important in today's society. Cooperative skills refer to the ability of children to work effectively with peers to complete tasks together [4]. In PjBL, children learn to communicate with peers, share resources, and allocate tasks through group projects and team activities, which fosters team spirit and collaboration skills [5]. Through hands-on project

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activities, children can develop social skills and self-confidence while gaining scientific knowledge [6].

To ensure that the design and development process of the PjBL module is both scientific and systematic, this study utilizes the 4-D model, which includes the four stages of Define, Design, Develop, and Disseminate, emphasizing the step-by-step refinement and structured implementation of teaching design [7]. In this study, the 4-D model is specifically used to guide the design and development of the PjBL module. With the help of the 4-D model, the operability of the PjBL module design can be ensured, thus providing a high-quality educational experience for preschool children.

In summary, this research will elaborate on how to use the 4-D model to design and develop the PjBL module, detailing the specific steps and implementation methods for each design stage. The aim is to provide a practical and feasible PjBL module in early science education for the field of Chinese preschool education, supporting the holistic development of children.

2. Methods and Results

2.1 Participants

Participants in this study included two preschool teachers and six children at a private kindergarten in Shandong Province, China. The number of participants was small because this study involved only a pilot test. The teachers were between 29 and 35 years old, all had a bachelor's degree in preschool education or a related field, and had between 7 and 12 years of teaching experience. The students participating in the study were all five years old, with three males and three females. Teachers and students were selected based on their willingness to participate voluntarily and were screened by the researcher.

2.2 Research Methods

This research integrates PjBL with preschool science education by developing PjBL modules based on constructivist theory and Vygotsky's theory of social development using the 4-D model. The purpose of this research is to address two questions. How can the PjBL module effectively develop preschoolers' critical thinking skills so that they can ask questions, analyze and solve scientific problems? How can the PjBL module promote cooperative learning and develop effective communication, teamwork and task assignment among young learners? Obviously, Piaget's concept of active exploration and Vygotsky's theory of zone of nearest development (ZPD) provide theoretical support for these questions [1]. Piaget's concept of active exploration refers to children constructing knowledge through experiential learning [8], while Vygotsky's zone of nearest development emphasizes the importance of guided learning within a collaborative framework [9]. These theories provide a solid theoretical foundation for designing and interpreting research findings.

The 4-D model is a systematic approach widely used in the field of educational design. The model consists of four stages, Define, Design, Develop, and Disseminate. This model emphasizes step-by-step and detailed planning and implementation in the teaching design process to ensure the effectiveness and relevance of educational activities [7].

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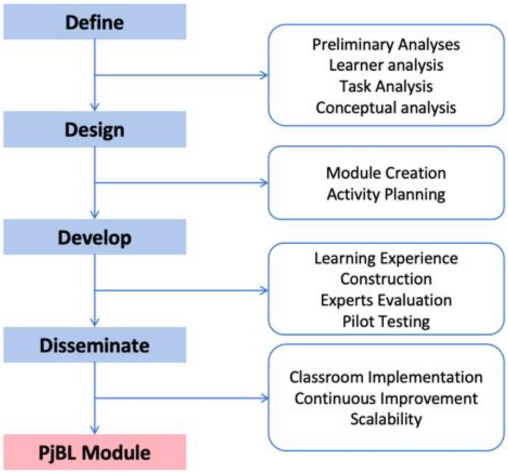

Fig. 1 Four Basic Elements of 4-D Model

The theoretical basis of the 4-D model can be traced back to constructivist theory. Constructivism believes that learners construct knowledge through interaction with the environment and active exploration [10]. The 4-D model embodies the core concept of constructivism by emphasizing learners' active participation and project-based learning. The model not only focuses on the design of learning content, but also attaches importance to evaluation and feedback in the learning process to ensure that teaching activities can truly meet learners' needs and development goals [7].

The reason for choosing the 4-D model lies in its highly structured and systematic characteristics. The 4-D model provides a clear framework that enables researchers to plan each stage in an organized manner. The Define and Design stages assist researchers in ensuring the scientific validity and practicality of the PjBL module content, while in the Develop and Disseminate stages, researchers can enhance the effectiveness of educational activities and facilitate their continuous improvement through feedback and revisions [11]. The 4-D model emphasizes practice and application, fostering children's critical thinking and problem-solving skills through project implementation. With a systematic evaluation and feedback mechanism, the 4-D model continuously refines the PjBL module, enhancing the quality of instruction to ultimately achieve the intended educational goals [12]. Fig. 2 illustrates the PjBL module framework designed based on the 4-D model.

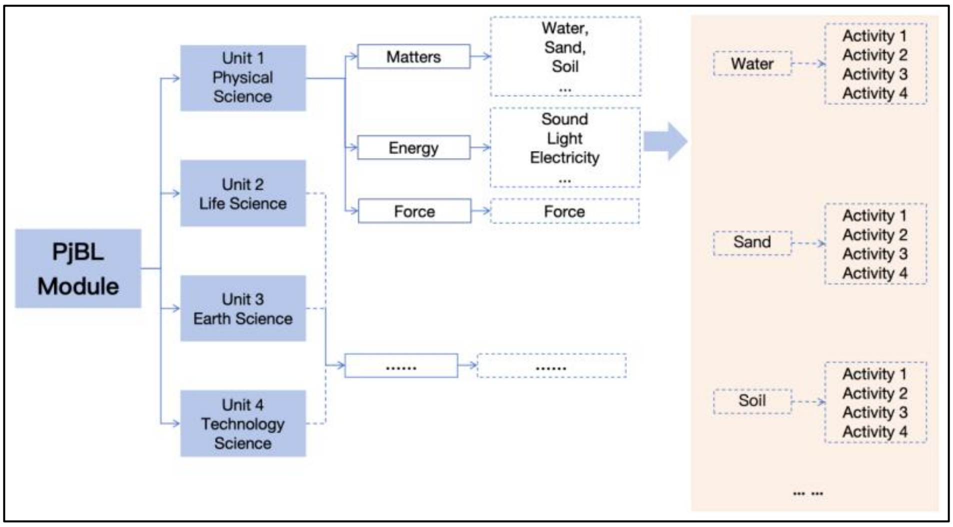

Fig. 2 PjBL Module Structure

The PjBL module designed in this study consists of four units. Each unit contains several sub-units, each sub-unit includes multiple themes, and each theme incorporates 3 to 5 specific

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teaching activities. This design aims to stimulate children's interest in learning and develop their critical thinking and cooperative skills through project-based learning.

Based on the 4-D model, this study aims to design and develop a PjBL module suitable for Chinese preschool children to enhance the development of their critical thinking and cooperative skills. The PjBL module provides children with a rich variety of learning content and activities while ensuring consistency and systematic structure in the teaching process for educators.

2.3 Definition Phase

2.3.1. Preliminary analysis

Preliminary analysis is the initial step in the 4-D model, aiming to gain a deep understanding of the background and needs of early science education in Chinese preschool education. The core of this step is to define the main content and objectives of early science education, providing clear guidance for subsequent design and development. In China, the importance of early science education is increasingly recognized. Its goal is not only to impart basic knowledge but also to cultivate children's comprehensive qualities and innovative abilities (Ministry of Education of the People's Republic of China, 2012).

According to the "Guidelines for Learning and Development of Children Aged 3-6" (MOE, 2012) and the "Guidelines for Kindergarten Education" (Ministry of Education of the People's Republic of China, 2001), the core objective of science education is to spark children's curiosity about their surroundings and encourage them to engage in active thinking and exploration. Early science education should cover the characteristics and patterns of change in common objects and phenomena, while providing rich, hands-on materials to allow children to explore with multiple senses. It should also cultivate children's cooperative skills and guide them to care for the environment and natural resources, fostering a basic sense of environmental responsibility (MOE, 2012).

Based on this, this study has identified core concepts and learning objectives in science education, including fundamental physical phenomena, life sciences, and earth sciences, which align with children's cognitive development patterns and satisfy their curiosity and exploratory needs (MOE, 2012).

Grounded in current Chinese preschool education documents, this study addresses the practical issues and challenges faced in science education and proposes a systematic early science PjBL module design, as shown in Tables 1 and Table 2.

Table 1. Example Repeated Header TableScientific content of the “Guidelines for Learning and Development of Children Aged 3-6”

Science Field	Age	Objective
Scientific Inquiry	3-4 years old	Like to contact nature and be interested in many things and phenomena around. Often ask various questions or play with objects out of curiosity.
	4-5 years old	Like to contact new things and often ask questions related to new things. Often use hands and brains to explore objects and materials and enjoy it.
	5-6 years old	Always get to the bottom of the questions that interest you. Often use hands and brains to find answers to questions. Feel excited and satisfied when you discover something during exploration.

(Ministry of Education of the People's Republic of China, 2001)

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Table 2. Scientific content of the "Guidelines for Kindergarten Education"

Science Field	Objective
Science	1. Be interested in things and phenomena around you, and have curiosity and thirst for knowledge. 2. Be able to use various senses, hands and brains to explore problems. 3. Be able to express and communicate the process and results of exploration in an appropriate way. 4. Be able to feel the quantitative relationship of things from life and games and experience the importance and fun of mathematics. 5. Love animals and plants, care about the surrounding environment, get close to nature, cherish natural resources, and have a preliminary awareness of environmental protection.

(Ministry of Education of the People's Republic of China, 2001)

2.3.2. Learner analysis

Learner analysis is the second step in the definition phase, aimed at assessing the initial developmental level of children, which forms the foundation for creating effective educational plans. Recent studies have shown that Chinese preschoolers exhibit significant individual differences in the development of critical thinking and cooperation skills (Jin, 2018). This phase supports the study in designing early science project-based learning activities that better meet the needs of preschool children. Research indicates that children aged 3 to 6 experience rapid cognitive development, allowing them to understand basic cause-and-effect relationships and scientific concepts [17]. Additionally, children in this age group show notable progress in social and language abilities, enabling them to engage in simple conversations and cooperative activities [17]. By gathering information on children's backgrounds, interests, and motivations, researchers can design teaching activities that are more relevant to children's real lives, thereby enhancing teaching effectiveness.

2.3.3. Task analysis

Task analysis is the third step in the definition phase. The goal is to break down early science education into specific tasks suitable for children, helping them gradually acquire scientific knowledge and skills. Science tasks suitable for preschool children should be simple and engaging to stimulate their interest in learning [18]. These tasks may include simple experiments, observation activities, and classification activities. Ensuring that these tasks align with children's developmental levels and educational goals can effectively enhance their scientific understanding and practical skills [18]. According to the "Guidelines for the Learning and Development of Children Aged 3-6" and the "Guideline for Kindergarten Education", science education activities should emphasize hands-on activities and inquiry processes. Specific task designs can include the following.

a. Observation and Recording. Cultivate children's observation skills and recording habits. b. Simple Experiments. Design simple scientific experiments to help children understand basic physical phenomena through hands-on activities. c. Classification and Comparison. Help children develop preliminary classification and comparison skills by sorting different objects or materials. d. Collaborative Exploration. Encourage children to engage in cooperative inquiry during group activities, enhancing their teamwork and social skills through discussion and sharing.

2.3.4. Conceptual analysis

Conceptual analysis is the final step in the definition phase, and identifying key science concepts and principles suitable for children is essential to the design of the PjBL module. Children's understanding of scientific concepts needs to align with their cognitive development level 2012). Within the context of China's preschool education policies and culture, key concepts in science education should include life science, physical science, earth science, and science and technology

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(MOE, 2012). These concepts should be presented through simple, engaging, and interactive activities, allowing children to experience and understand them in real-life contexts.

a. Life Science. Through planting activities, children can learn about the growth process of plants and understand their basic needs and growth conditions. b. Physical Science. By engaging in simple physical experiments, such as magnet attraction and repulsion, children can grasp basic physical principles. c. Earth Science. By observing and recording weather changes, children can develop an initial understanding of the concepts of seasonal changes and weather phenomena. d. Science and Technology. By exploring the basic operating principles of household appliances, children can recognize the application and importance of technological products in daily life.

The learning and practice of these concepts help children acquire scientific knowledge, spark their curiosity and spirit of inquiry, and lay a solid foundation for their future learning and development.

2.4 Design Phase

2.4.1. Module Creation

The purpose of module creation is to build a PjBL module framework that enables young children to apply knowledge, solve problems, and collaborate in real-life situations. At this stage, it is essential to clearly define the learning objectives of the PjBL module to ensure effective evaluation of children's learning progress and developmental needs [19]. Table 3. outlines some components of the early science project-based learning implemented in this study. The content of Table 3. is derived from the "Guidelines for Learning and Development of Children Aged 3-6." The scientific literacy emphasized in the "Guidelines for Learning and Development of Children Aged 3-6" mainly includes stimulating children's curiosity for exploration, developing basic inquiry skills, recognizing objects and phenomena around them, understanding scientific concepts, and applying them in real-life contexts (MOE, 2012). Specific elements include enhancing children's logical reasoning and classification skills through observation, comparison, and experimentation. Project activities and hands-on practical activities foster cooperative skills and problem-solving abilities (MOE, 2012). Additionally, children should be guided to understand the objective world, learn the essential characteristics of objects, and grasp the relationships between various phenomena, allowing them to gain more scientific experiences through practice (MOE, 2012).

Table 3. Early science teaching module design

Unit	First Level Topic	Secondary Topics (Examples)	Main purpose
Unit 1: Physical Science	Unit 1.1: Matter	Water, sand, soil, etc.	By exploring the properties of different substances, cultivate children's observation ability and experimental interest, and help them understand the diversity of substances.

2.4.2. Activity planning

In activity planning, it is essential to design specific activities for each theme in detail to ensure that the activities can spark young children's interest and encourage their active participation. According to the "Guidelines for Kindergarten Education," science tasks suitable for preschool children should be simple and engaging. Table 4. provides examples of the design of some specific activities.

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Table 4. Early science teaching activity design (example)

Unit	First Level Topic	Secondary Topics (Examples)	Main Activities (Examples)
Unit 1: Physical Science	Unit 1.1: Matter	Water	Experiment on the floating and sinking of water: Make small boats with different materials and observe how they float and sink in water.
		Sand, soil	Comparison of sand and soil: Let children use a magnifying glass to observe the differences between sand and soil and try to classify them.

In the PjBL module designed for this study, different aspects of each activity were able to enhance children's critical thinking skills and cooperative skills. The following are examples of specific activities and their associated components.

In Example 1, Floating and Sinking of Water, the following components of the experiment enhanced children's critical thinking.

a. Asking questions. At the beginning of the activity, the teacher asks the children the question, "Why do some objects float on the surface of the water and others sink?" This session stimulates children's curiosity and desire to investigate.

b. Designing experiments. Children were encouraged to discuss and design how to test the floating and sinking of boats made of different materials in water. This session developed their logical reasoning and experimental design skills.

c. Data collection and analysis. During the actual operation, children collected data and analyzed them by observing and recording the performance of the boats of different materials in the water. This session improved their ability to analyze and evaluate data.

d. Drawing conclusions. Based on the results of the experiment, children discuss and draw conclusions to understand which materials are more suitable for making boats that float on water. This process develops their ability to summarize and generalize.

The following components of the Example 1 "Water Floating and Sinking" experiment enhance children's cooperative skills.

a. Group work. Children were divided into small groups to conduct the experiment, with each group member responsible for different tasks, such as preparing materials, conducting the experiment, and recording the results. This session enhanced their task allocation and cooperation skills.

b. Communication. During the experiment, children needed to communicate and discuss constantly, sharing their observations and insights. This session promotes their communication skills and teamwork.

c. Group discussion. After the experiment, children had a collective discussion under the guidance of the teacher to analyze the results and summarize the experience together. This session further strengthened their cooperation and collective decision-making skills.

Through carefully designed PjBL science activities, researchers enhanced children's critical thinking and cooperative skills by engaging them in questioning, experiment design, data collection and analysis, and drawing conclusions, thereby developing logical reasoning and evaluative abilities. These activities, which incorporate age-appropriate, engaging tasks, foster teamwork, communication, inquiry spirit, and hands-on skills, supporting children's comprehensive growth in scientific knowledge, skills, and attitudes. The interactive, practical nature of these tasks also gives children a sense of accomplishment in exploration, further sparking their interest in scientific inquiry.

2.5 Development Phase

2.5.1. Learning experience

The purpose of learning experience construction is to transform theories and designs into practical teaching. Learning experience refers to the process through which children acquire

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knowledge, skills, and attitudes by engaging in various activities and interactive processes. In the PjBL module, learning experience is not about passively receiving information; rather, it involves children actively participating, exploring, and cooperating in real-life situations.

Interactive experiments play a vital role in PjBL. Through hands-on experiments, children can directly observe and explore scientific phenomena. By identifying and solving problems within these activities, children deepen their understanding of scientific concepts and enhance their critical thinking skills. Experimental activities need to consider children's cognitive abilities and ensure that they can conduct the experiments safely under the teacher's guidance [6]. Group work is another key aspect of PjBL. In group activities, children can share resources, assign tasks, and learn how to communicate effectively with others. Group collaboration is an important way to develop children's cooperative skills [20]. In developing learning experiences, it is essential to provide instructional materials that match children's cognitive levels and educational standards. These materials should be simple, easy to understand, and accessible for children (MOE, 2001). This includes specific items needed for experiments, as well as books, videos, and other multimedia resources to support instruction. Table 5. shows the detailed design of the learning activities.

2.5.2. Construction

Table 5. is an example of Early Science Learning Experience Construction and is not the full Module.

Table 5. Early Science Learning Experience Construction (Example)

Modules (Example)	First Level Topic (Example)	Secondary Topics (Examples)	Activities (Examples)	Activity Content	Teaching Materials/Tools
Physical Science	Matter	Water	Water buoyancy experiment	Children use different materials to make small boats, observe their floating and sinking in the water, and learn about buoyancy.	Water tank, boat model (different materials)
		Sand, soil	Magnet experiment	Use magnets to attract different metal objects and observe the effect of magnetism	Magnets, metal objects

The floating and sinking experiment in Table 5. further enhances children's critical thinking skills in subsequent activities. In this experiment, children engage in hands-on activities to understand the concept of buoyancy. By making and observing boats that float or sink, they raise questions such as, "Why do some boats float while others sink?" and attempt to explore answers. This process encourages children to observe, hypothesize, experiment, and analyze results, thereby strengthening their critical thinking skills. Additionally, children's cooperative skills are developed in the following experimental stages. When conducting the floating and sinking experiment in groups, children work together to build boats, share observations, and discuss the reasons behind floating and sinking. Throughout the activity, they communicate effectively, collaborate in task distribution, and share resources, thus enhancing teamwork and cooperative skills.

Through interactive experiments and group work in PjBL activities, children gain knowledge while enhancing their critical thinking and cooperative skills. Questioning, experimental observation, reasoning, and summarizing in the activities effectively improve children's critical thinking, while resource sharing, task allocation, and collaborative discussions foster their cooperative skills.

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2.5.3. Experts Evaluation and Result

The purpose of experts evaluation is to gather feedback from educational experts during the PjBL module development process to ensure the module's relevance and effectiveness. In this study, two experts from China, with extensive research and practical experience in preschool education, were invited. Once the module development was completed, the experts conducted a comprehensive evaluation of its design and implementation. After the development phase, the researcher prepared detailed design and development documents, including teaching objectives, content, strategies, assessment methods, and teaching resources. These documents provide the experts with a full understanding of the module's various aspects.

Following this, the researcher organized an online review for the experts, who thoroughly assessed the module, completed review forms, and provided written feedback. Based on the experts' feedback, the researcher made necessary adjustments and improvements to enhance the module's scientific validity, effectiveness, and practicality. Once all adjustments and improvements were finalized, the researcher validated the final version of the module and prepared it for the dissemination phase.

An analysis of the expert review results of the PjBL module shows that the experts rated the module highly in several areas, while also identifying a few areas for further optimization, as shown in Figure 3.

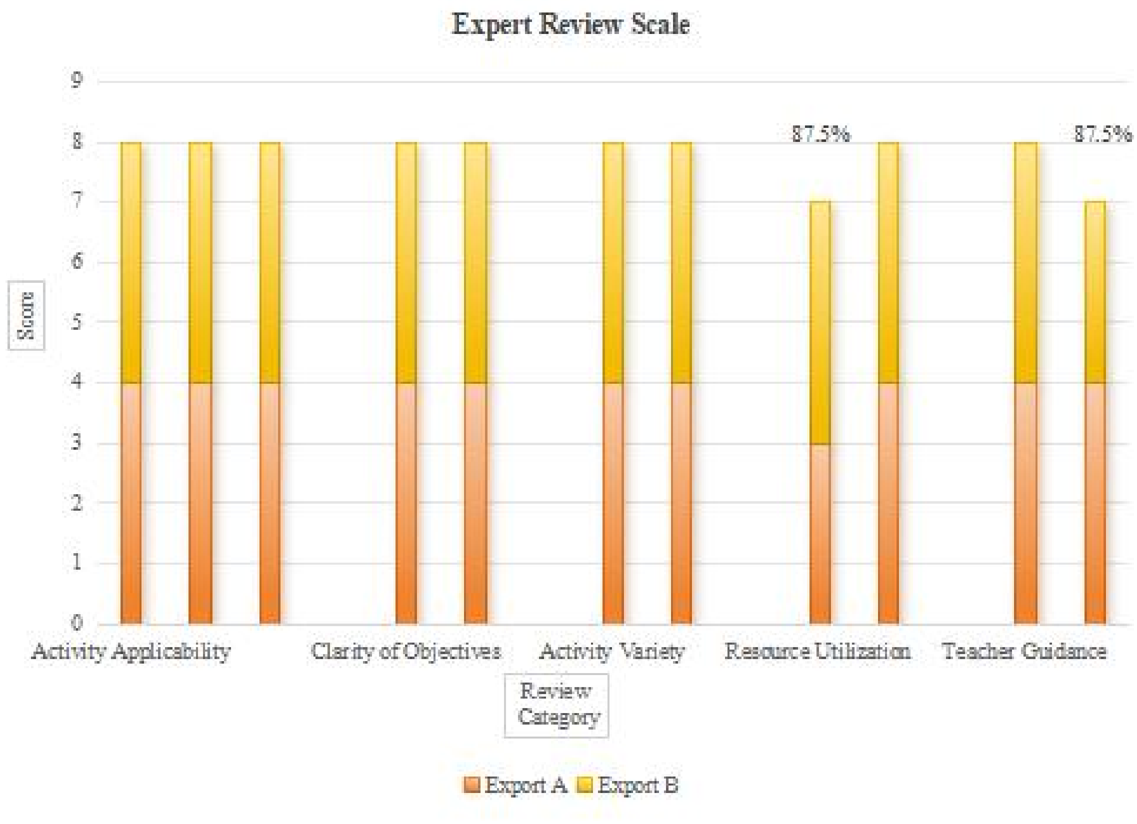

Fig. 3 Expert Review Scale - PjBL Module

The strengths of the expert review results are quite evident. The scores indicate that the activities in the PjBL Module are highly suitable for early childhood science education, with content aligned to young children's cognitive development levels, effectively sparking their interest in learning and exploration. This suggests that the module design is appropriate, capturing children's attention while matching their developmental stage. The clarity and specificity of the learning objectives were also recognized by experts, showing that the module successfully conveys learning goals aimed at fostering critical thinking and cooperative skills. The diversity of activities received high praise as well, the module includes activities suited to various learning styles and approaches, which not only

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enriches the content but also promotes children's cognitive and social development. This variety in teaching strategies helps cater to children with different needs, ensuring that each child benefits from the module.

Next are the areas needing improvement. In terms of resource access and utilization, although most resources were rated highly in terms of accessibility and educational effectiveness, the ease of resource access scored slightly lower (87.5%). This suggests that, while resources are effective in educational use, there may be minor barriers to accessing them, though these issues are manageable. This may relate to the cost, accessibility, or specific conditions needed for implementation. The practical application of teacher guidance also received a slightly lower score (87.5%), particularly regarding how teachers organize and conduct mentoring activities. This indicates that, while the teacher guide is sufficient in theory, its practical use may require additional support or clearer implementation guidelines to help teachers utilize it more effectively.

Overall, the experts gave the PjBL module high marks. They found the module rich in content and well-designed activities that effectively stimulate children's interest in learning and desire to explore, demonstrating the PjBL module's potential for application in early childhood education. Additionally, enhancing the ease of resource access and the practicality of teacher guidance will make the module even more refined and responsive to educational practice needs. This feedback provides valuable insights for ongoing improvements, ensuring the module better serves early education settings.

2.5.4. Pilot Testing and Result

The final step is the pilot test. Before formal implementation, researchers conducted a two-week small-scale pilot of the PjBL module, selecting six children to participate in a series of activities centered around the theme of "water". During the pilot test, researcher observed and assessed the children's reactions and engagement to ensure the module's feasibility in actual teaching settings.

For this pilot test, six children from a preschool class were chosen (to protect their privacy, they are referred to as A, B, C, D, E, and F). The test lasted for two weeks and included various activities focused on the "water" theme. Details of the specific activities are provided in Table 6.

Table 6. Pilot Testing Scientific Activities

Activity Type	Activity Content	Teaching Objectives	Teaching Materials
Water floating and sinking experiment	Children use different materials (such as wood blocks, plastic bottle caps, plasticine, etc.) to make boats and observe how they float and sink in the water.	Understand the basic concepts of buoyancy and gravity, and cultivate children's observation and analysis abilities.	Water tank, boat model materials (wooden blocks, plastic bottle caps, plasticine, etc.).
Water color change experiment	Children use different food coloring to dye water, observe the color changes, and mix different colored water to explore the color change patterns.	Understand the basic principles of color mixing, and cultivate children's hands-on and observation abilities.	Transparent cup, food coloring, stirring stick, water.

During the pilot test, this study used quantitative assessment methods to comprehensively evaluate the children's performance.

The quantitative assessments used observational rating scales to quantitatively rate the children's key behaviours and to assess their performance in critical thinking and cooperative skills. Figures 4 and 5 visualise the results of these assessments. The scores include analytical skills, reasoning skills, problem-solving skills, effective communication and task allocation, and the charts reflect the specific performance and progress of each child on these key behavioural indicators through the use of radar charts.

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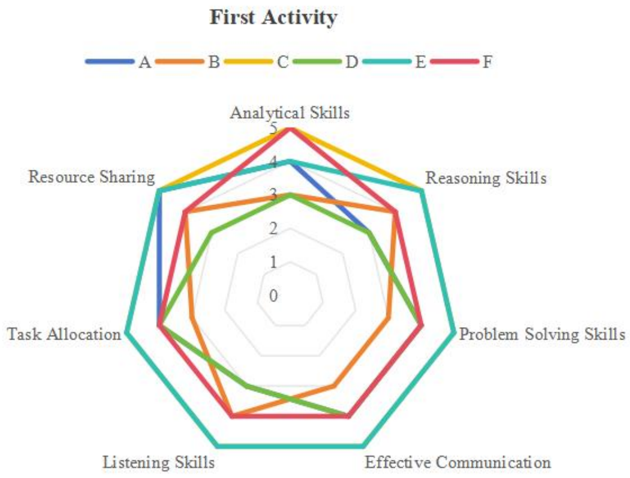

Fig. 4 Quantitative Assessment of the First Activity

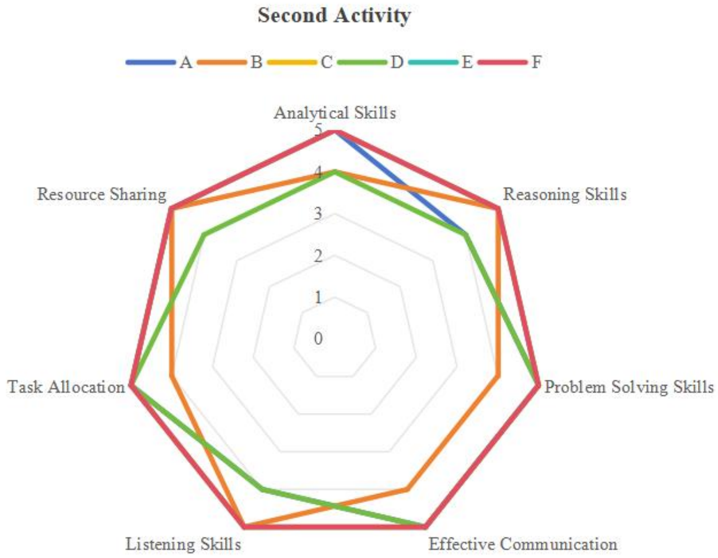

Fig. 5 Quantitative Assessment of the Second Activity

Figures 4 and 5 show the key behaviours of the six children in the two science activities, including analytical skills, reasoning skills, problem solving skills, effective communication, listening skills, task allocation and resource sharing.

In the first activity, C and E performed the best, A and F performed better, and B and D performed relatively weakly. Specifically, A performed better on analytical skills, problem solving skills, effective communication and task allocation with a score of 4, but needed to improve on reasoning skills and listening skills with a score of 3. B scored higher on reasoning skills and listening skills with a score of 4 but scored a 3 on the other behavioural indicators.C performed well on all the behavioural indicators with a score of 5. D scored well on effective communication, problem solving skills and task allocation, but scored a 4 on all other behavioural indicators. e excelled on all behavioural indicators with a score of 4 or 5. f scored a 5 on resource sharing and a 4 on all other behavioural indicators.

In the second activity, all children improved their performance.A improved to a score of 5 on all behavioural indicators.B improved to a score of 5 on Reasoning Skills and Listening Skills, and scored a 4 on all other behavioural indicators.C maintained a score of 5 on all behavioural indicators.D improved to a score of 5 on Analytical Skills, Reasoning Skills, Problem Solving Skills, Effective Communication, and Task Assignment, and showed significant improvement.E continued

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to perform well on 5 on all behavioural indicators. f improved to 5 on all indicators with excellent performance.

Comparison of the two activities show that children's abilities on key behavioural indicators improved significantly, particularly in reasoning skills, problem-solving skills and effective communication. These improvements suggest that project-based science activities are effective in improving children's skills in analysis, reasoning, problem solving, communication, listening, task management and resource sharing.

During a two-week pilot test, the PjBL module received positive feedback and good implementation effects among 6 children. Children show great interest and enthusiasm in activities and can actively participate in interactive experiments and group projects. Through group projects, children learn to communicate effectively and assign tasks, and their cooperation skills are significantly improved. Children have a preliminary understanding of scientific concepts such as the buoyancy of water through experiments and projects. Children demonstrate strong critical thinking skills in solving problems and formulating hypotheses. Due to the significant success of the pilot test, no major problems were found in the PjBL module and it can be put into actual teaching.

2.6 Dissemination Phase

2.6.1. Classroom Implementation

After completing the development of the PjBL module, implementing it in the classroom is a crucial step to verify its practical effectiveness. The focus of this stage is to integrate the module into a real teaching environment and continually refine and enhance the teaching design through observation and feedback.

Effective classroom implementation of the PjBL module requires thorough planning and preparation. Teachers should first become familiar with the module's content and structure, clarifying the objectives and steps of each teaching activity. During the actual implementation, teachers should follow the module guidelines to gradually guide children in participating in interactive experiments and group projects. In this process, teachers act not only as transmitters of knowledge but also as facilitators and supporters of children's inquiry-based learning [20].

Observing children's reactions and participation is a key element during implementation. Teachers should closely monitor children's performance in different activities, recording their level of engagement, interests, and any challenges they encounter. These observations provide valuable insights for subsequent adjustments. If certain experimental steps are too complex for children to understand or manage, teachers can make adjustments, simplify steps, or offer additional guidance as needed [6]. Based on classroom feedback, teachers should continuously refine the module, which includes adjustments to the teaching activities themselves as well as improvements to teaching materials and resources. Through ongoing adjustments, the module can better meet children's learning needs and enhance teaching effectiveness.

2.6.2. Continuous Improvement and Results

Continuous improvement ensures that the PjBL module maintains consistency and effectiveness in actual teaching. In this process, feedback from teachers and children is crucial. Continuous improvement requires teachers to regularly collect and analyze children's feedback to understand the impact of teaching activities on them.

Researchers should systematically evaluate and enhance the module based on feedback. This includes a comprehensive review of the content, structure, and implementation methods of teaching activities, making adjustments as needed. For instance, if certain activities are generally considered too simple or too complex, researchers can redesign them to better align with children's cognitive development levels and interests.

During the improvement process, teachers should also engage with other educators. Sharing practical teaching issues can lead to more suggestions for improvement. Teachers can participate in

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professional training and workshops to learn the latest teaching concepts and methods, which can then be applied to further optimize the PjBL module [6].

Through continuous optimization and improvement, the PjBL module's effectiveness in teaching can be enhanced, while also promoting teachers' professional growth and elevating their teaching skills.

2.6.3. Scalability and Results

Scalability is essential to ensure that the PjBL module can be widely applied across various teaching environments. At this stage, researchers assess the adaptability and potential for broader implementation of the module in different educational contexts based on existing research.

Researchers need to consider the module's applicability across different regions, schools, and classes. By conducting pilot tests in diverse environments, the effectiveness and adaptability of the module in varied educational settings can be evaluated. In future studies, different types of kindergartens can be selected for testing, gathering feedback from multiple perspectives to understand how the module performs in different contexts.

Researchers should also consider the module's suitability for children of various age groups. Although this study primarily targets children aged 3-6, the design and content of the module can be adjusted and optimized according to the cognitive development characteristics of each age group. More complex experiments and projects can be developed to meet the needs of children over 6 years old.

Through these measures, the PjBL module can be widely applied in different educational settings, providing more children with high-quality learning experiences and supporting their overall development.

3. Discussion

3.1 Impact of Pilot Study

In the pilot study, six children were highly engaged. With the implementation of the PjBL module, children demonstrated active exploration and hands-on skills in science experiments and project activities. From teacher-led initial questioning and hypothesis formation to experimental design and analysis of results, children demonstrated an exploratory spirit. Through systematic project design and activity scheduling, children were no longer passive recipients of information but were able to ask questions, think and try to solve problems when faced with scientific problems.

The results of the comprehensive pilot test showed that children gradually improved their cooperative skills and critical thinking skills in the process of observation, recording and discussion. The results of the pilot research are consistent with the underlying principles of constructivism and developmental theory. The improvement in critical thinking and cooperative skills observed in the activities can be attributed to the problem-to-school and group collaborative design of the PjBL module. This result supports Vygotsky's theory that peer collaboration develops cognitive skills, in this case specifically critical thinking and cooperative skills, through joint problem solving and mutual support [21]. Additionally, Piaget's theory is reflected in the hands-on program where children identify problems, analyze them, and solve them through mutual discussion and collaboration [22]. The key to the success of the PjBL module in this research was the use of real-life problems to capture children's attention, which was a key factor in activating children's curiosity. Throughout the process, children learnt to make scientific observations and record experiments, and also learnt to cooperate with their peers to solve problems together. These activities effectively promoted children's cognitive and social development.

The success of the pilot test has validated the great potential of the PjBL module in promoting early childhood science education and the development of integrated competence. This teaching model will be further improved and promoted in the future so that more young children can benefit from the educational innovations brought about by project-based learning.

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3.2 Continuous Improvement and Scalability

The PjBL module demonstrated several strengths in this study.PjBL was able to stimulate children's interest in learning and desire to explore through hands-on projects and experimental activities. By participating in the projects, children are no longer passive recipients of knowledge, but become active explorers who show great curiosity and enthusiasm for hands-on activities. The module design is systematic and scientific, which can help teachers to organise and implement teaching activities effectively. Through the systematic design, teachers are able to teach in a more organised manner and ensure that each step is carried out effectively. In addition, the PjBL module focuses on the development of children's practical ability and cooperative spirit. Through group activities and team projects, children are able to practise and enhance their communication, coordination and teamwork. These activities not only promoted children's social skills, but also enhanced their self-confidence and sense of responsibility.

Although the PjBL module achieved good results in the pilot test, it also revealed some issues that need to be improved. In terms of access to and use of resources, feedback from the expert review indicated that certain experimental materials were difficult or costly to obtain. This problem has to a certain extent limited the development and promotion of the activities. Meanwhile, it was also mentioned in the expert review that certain experimental steps were more complicated for younger children, which led to children's confusion and frustration during the activities. In order to cope with these problems, the researcher carried out corresponding improvement measures, including optimising the experimental design, simplifying the operation steps, and providing more suggestions for alternative experimental materials. These improvements were made to ensure that the activities were more adapted to the cognitive developmental level of the children and to increase the operability and participation of the activities.

Several issues remain in this study.The applicability of the PjBL module in different educational settings and disciplines is an issue that was not explored in this study. This study mainly focused on the application of the PjBL module in early science education, but did not delve into its extended application in other disciplines such as language, maths and art. In addition, the applicability of the modules in different types of kindergartens (e.g., urban and rural, private and public) has not been adequately tested. Although the PjBL modules are designed to be flexible and can be adapted to the cognitive developmental levels of children of different ages, their actual effectiveness in diverse educational settings requires further empirical research to ensure that every child can benefit from them.

Future research could further explore the effectiveness of the PjBL module in different disciplines and educational settings, especially on children's critical thinking and cooperative skills. This study focused on the application of the PjBL modules in early science education, but future research could be extended to other disciplines such as language, maths and art to validate the applicability and effectiveness of the modules in these areas. The future also allows for a comprehensive evaluation of the actual effectiveness of the PjBL modules in diverse educational settings, with studies and tests conducted in different countries, in different regions, and in different types of kindergartens (e.g., urban and rural, private and public). Future research should also focus on the impact of the PjBL modules on teachers' professional development and explore how the implementation of the modules can enhance teachers' pedagogical competence and professionalism.

4. Conclusions

This research focuses on the design and development of project-based learning (PjBL) modules for the early science field in China. The importance of PjBL in modern education is emphasised, particularly in enhancing critical thinking and cooperative skills. This research emphasizes the strong connection between the PjBL module and preschool and educational theories, particularly those of Piaget and Vygotsky. This research emphasizes exploration, collaboration, and problem-guidance, and the PjBL module demonstrates its effectiveness as a means of developing

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critical thinking and cooperative skills in early science education. This inquiry-based approach ensures that children are not passive recipients of knowledge, but are actively engaged in their own learning process.

The research adopted a 4-D model, incorporating constructivist theory to ensure a structured and systematic educational design process. The definition phase analysed the current situation and needs of preschool science education in China, and the design phase created a systematic framework of PjBL modules detailing learning objectives and activities to develop children's critical thinking and cooperative skills. The development phase enhanced children's critical thinking and cooperative skills through interactive experiments and group work, and expert evaluation provided feedback and made necessary adjustments. Pilot testing showed that the modules were successful in engaging children and enhancing their skills. The dissemination phase allowed for continuous optimisation of the instructional design through feedback from teachers and children. The research also acknowledged several limitations.The applicability of the PjBL modules in a variety of educational settings and disciplines still needs to be further explored. Future research should be extended to other disciplines such as language, maths and art to validate the effectiveness of the modules in these areas. There is also a need to evaluate the actual effectiveness of the PjBL modules in different types of kindergartens.

Overall, the early science PjBL module shows great potential in enhancing children's critical thinking and cooperative skills. By continually optimising and expanding the use of the modules, educators can provide more children with high-quality educational experiences that foster critical thinking, cooperative skills and holistic development.

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