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Original Research Article

Building a Scientific Competency Framework for Vietnamese Preschool Children

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Abstract: Scientific competence is essential in preschool education as it fosters foundational thinking and problem-solving skills, paving the way for children's engagement with STEM fields. Young children are naturally inquisitive, and early exposure to scientific thinking helps nurture observation, questioning, and experimentation abilities. However, many current preschool curricula, including in Vietnam, lack a clear framework for developing and assessing scientific competence. This study proposes a conceptual framework to integrate science education systematically into preschool programs. Using literature review, content analysis, and the Delphi method, the study identifies five core components of scientific competence: critical thinking, experimental thinking, observation skills, questioning skills, and problem-solving. These elements reflect key scientific abilities children can acquire through exploration and guided activities. The proposed framework offers practical tools for teachers to design and evaluate science-based learning. Future studies should implement this framework in real classroom settings to assess its effectiveness and refine it for better applicability in Vietnam's preschool context.

Keywords: Scientific Competence, Early Childhood Education, Conceptual Framework, Inquiry-based Learning.

1. INTRODUCTION

In the era of the Fourth Industrial Revolution, scientific capacity is a vital requirement across all educational levels, including preschool. Early science education builds a foundation for logical thinking, creativity, and problem-solving skills. It fosters children's natural curiosity and supports the development of observation, questioning, and experimental abilities. Studies by Piaget and Vygotsky affirm that preschoolers can form basic scientific concepts through hands-on, visual experiences. Internationally, many countries have integrated science into early education. The U.S. applies the NGSS to promote scientific thinking through play, the UK's EYFS links science with everyday activities, and Australia's Little Scientists program emphasizes small projects to develop reasoning skills. However, in Viet Nam, preschool science education lacks a formal competency framework. Content is mostly embedded in natural exploration activities without specific learning goals, making teaching and assessment inconsistent.

Teachers also face challenges due to insufficient training and resources. Existing global scientific competency models (e.g., PISA, NRC) are not tailored to preschoolers' cognitive needs. Thus, building a specific framework for preschool science competency in Viet Nam is essential. It will help define key competencies, support curriculum design, and provide assessment tools, guiding science education to be more systematic and aligned with young children's development.

2. LITERATURE REVIEW

2.1. Concept of scientific capacity

The concept of scientific competence has been mentioned in many educational studies and is considered an important factor in preparing the younger generation to adapt to the rapid development of science and technology (Bybee, 2020). Scientific competence is not simply the acquisition of scientific knowledge but also involves the ability to apply knowledge, think critically, ask questions and solve problems using scientific methods (OECD, 2019). According to the National Research Council (2018), scientific competence includes three core components: 1) Conceptual understanding of science: Includes knowledge of basic scientific principles, laws, and concepts. 2) Scientific practices: The ability to conduct experiments, collect data, analyze results, and draw conclusions. 3) Applying science to real-world situations: The ability to use scientific

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knowledge to solve problems in everyday life. Another approach, Lederman et al. (2019) emphasize that scientific competence is not limited to understanding scientific principles but also includes the ability to ask questions, think critically, and use the scientific method to verify information.

Many educational organizations around the world have proposed different definitions of scientific competence, reflecting the multidimensional approach of this concept. According to the OECD (2018), in its report on the assessment of scientific competence of PISA students, scientific competence is defined as "the ability to engage with science-related issues, understand scientific ideas, and apply scientific methods to analyze and solve practical problems". According to the National Research Council (2012), scientific competence is not only theoretical knowledge but also includes the ability to reason based on evidence, think critically, and apply knowledge to real-world situations. The Next Generation Science Standards (NGSS, 2013) describe scientific competence as a set of skills that include observing, asking questions, reasoning based on evidence, and using technology to support scientific discovery.

The concept of scientific competence is often confused with scientific literacy. Although closely related, the two concepts have fundamental differences. Accordingly, scientific competence refers to the ability to apply scientific skills, knowledge, and methods to solve problems, ask questions, and participate in scientific activities (Bybee, 2020). This is a set of specific skills that help individuals practice science effectively. Meanwhile, scientific literacy refers to the ability to read, understand, interpret, and evaluate scientific information in real-life contexts (Roberts & Bybee, 2019). It emphasizes understanding scientific concepts to make informed decisions in everyday life.

Criteria	**Scientific Competence**	**Scientific Literacy**
Target	Apply scientific methods to solve problems	Understanding and evaluating scientific information in life
Main ingredients	Scientific practice skills, asking questions, solving problems	Scientific knowledge, critical thinking, ability to evaluate information
Applicable context	In the environment of learning, research, scientific work	In real life situations
Illustrative example	A student conducts an experiment to find out the effect of light on plant growth.	An adult reads an article about climate change and decides whether to change his or her consumer behavior.

Despite their differences, scientific competence and scientific literacy are closely related. An individual with high scientific competence will likely have good scientific literacy, as they are able to use scientific thinking to analyze and evaluate information. Conversely, a person with scientific knowledge but lacking scientific literacy may understand scientific concepts but lack the ability to practice or systematically verify information (OECD, 2019). In preschool education, the goal is not only to help children develop scientific competence but also to develop scientific understanding that can be applied to real life later on (McClure *et al*., 2021). Therefore, the construction of educational programs needs to balance these two aspects to ensure that children are both able to practice science and can apply knowledge in a meaningful way.

2.2. Approach to science education in preschool

Science education in preschool is increasingly focused on building a foundation of early scientific thinking for children. Popular approaches include inquiry-based learning, STEM education, and the application of science education programs in real life.

2.2.1. Inquiry-Based Learning

Inquiry-Based Learning (IBL) is a pedagogical approach in which children explore the world through observation, questioning, experimentation, and drawing conclusions. This approach is consistent with the curious and inquisitive nature of young children (Fleer, 2019). IBL does not focus on one-way knowledge transmission but encourages children to think independently, practice, and verify information. Teachers act as guides, facilitating children's exploration rather than providing direct answers (Eshach & Fried, 2018).

According to Bell *et al*. (2019), there are four levels of discovery learning in early childhood education:

Level	**Describe**	**For example**
Guided Discovery	Teachers ask questions and guide children to observe and experiment.	The teacher asks the children to predict which objects will sink or float, then lets them practice to verify.
Explore by Direction	The teacher poses the problem, but the children come up with the solution themselves.	The teacher asks the question: "How can we help the doll move on the water?" and lets the children find a solution themselves.
Open Discovery	Children ask questions and experiment without specific instructions.	Children watch ants crawl and make their own hypotheses about where they go.

Integrated Discovery	Combining multiple levels of exploration, children learn from instructions and actively explore.	Children plant their own plants, observe their growth, and record the results over time.

2.2.2. STEM education and its role in developing scientific capacity

STEM (Science, Technology, Engineering, and Mathematics) is an educational method that integrates science, technology, engineering, and mathematics to help children develop systematic thinking and problem-solving skills (Bybee, 2020). STEM education in preschool does not teach each subject separately but integrates them into practical activities, helping children access scientific knowledge in the most natural way (Greenfield *et al*., 2019).

According to research by McClure *et al*. (2021), STEM education in preschool includes: 1) Science: Observing, asking questions, and conducting simple experiments. 2) Technology: Using supporting tools (such as magnifying glasses, measuring rulers) to explore the world. 3) Engineering: Building, designing, and testing simple models. 4) Mathematics: Recognizing shapes, measuring, counting, and analyzing simple data.

2.2.3. Some science education programs for preschool children

Many countries have implemented science education programs for preschool children to encourage early scientific thinking. Some typical programs include: "Early Years STEM" program (UK, 2019): Encourages children to participate in scientific discovery activities through play and practical experiments (Cheng *et al*., 2019). OECD's Inquiry-Based Science Education (IBSE) program (2021): Applying discovery-based learning methods, helping children develop observation and questioning skills. "Little Scientists" program (Australia, 2020): Aims to integrate science education into children's daily activities.

In Vietnam, science education for preschool children is still new, but there are some programs integrating STEM and learning through discovery: New preschool education program (Ministry of Education and Training, 2018): Has begun to integrate scientific activities into teaching. STEM education models in preschools: Some schools have implemented STEM activities such as simple experiments and making engineering models. "Children have fun exploring" program: Tested in some preschools, helping children approach science through games and practice. It can be said that approaches such as discovery learning, STEM education and science education programs have shown to be effective in developing scientific thinking in preschool children. However, to achieve higher efficiency, there needs to be investment in curriculum, teacher training and building a suitable learning environment.

2.3. Assessment of scientific ability of preschool children

Assessment of scientific competence plays an important role in education, helping to measure the level of development of scientific thinking skills and the ability to apply scientific knowledge in practice. In the world, many models of scientific competence assessment have been built, the most notable of which are the scientific competence framework in PISA, the OECD scientific competence model and the NRC model (National Research Council, USA). However, a major challenge is that these assessment models are mainly applied to primary, secondary and tertiary students, while early childhood education has very different characteristics. Therefore, it is necessary to consider the suitability of these models for preschool children.

2.3.1. Science competency framework in PISA

The Programme for International Student Assessment (PISA) is conducted by the OECD every three years to measure the abilities of 15-year-old students around the world in the fields of Mathematics, Reading and Science. According to the OECD report (2018), PISA assesses scientific competence based on three main criteria: 1) Explaining scientific phenomena: Students can use scientific knowledge to describe and explain natural phenomena. 2) Evaluating and designing scientific investigations: The ability to understand scientific research methods and assess the reliability of data. 3) Interpreting data and drawing scientific conclusions: Using data to analyze, draw conclusions and evaluate their accuracy. Although PISA focuses on 15-year-olds, some of its assessment principles can be adapted to apply to preschool children. For example, children can be assessed based on their ability to observe and explain scientific phenomena instead of understanding complex concepts. Scientific exploration and practice activities can replace traditional testing assessments. Several studies have proposed approaches to assessing young children's science competencies based on PISA principles, such as assessment through experimental activities instead of written tests (McClure *et al*., 2021).

2.3.2. OECD and NRC (National Research Council, USA) scientific capacity model

In addition to PISA, OECD also proposed a broader model of scientific competence, which emphasizes three elements: 1) Scientific knowledge: Knowledge of scientific concepts. 2) Scientific process: Ability to ask questions, conduct research and test hypotheses. 3) Science in society: Understanding the impact of science on society and the environment. In preschool education, this model can be applied by assessing children's ability to observe, ask questions and explain phenomena. The NRC (National Research

Council, USA) model of scientific competence proposes a model of scientific competence based on three main pillars: 1) Understanding scientific concepts. 2) Scientific and engineering practices. 3) Understanding the nature of science. This model emphasizes that learning science is not only about acquiring knowledge but also about practicing scientific thinking skills, which is very suitable for preschool education. Although the above assessment models are valuable in science education, when applied to preschool children, there are some challenges that need to be considered: Children do not have the ability to read and write fluently, so traditional tests such as PISA cannot be used. Children's scientific thinking is mainly based on observation, experimentation and practical exploration, rather than abstract reasoning. Children's ability to concentrate and perceive science is limited, so flexible assessment methods are needed, suitable for cognitive development. Based on the OECD and NRC guidelines, assessing preschool children's scientific competence can be done through: Observing children's behavior and how they respond to scientific phenomena (e.g., Do they ask questions when they see water evaporating?). Experimental activities: Let children participate in scientific games and assess how they interact with the environment. Assessment through learning products: For example, asking children to draw a scientific phenomenon or recount what they observed. Interviews and conversations: Teachers can ask questions such as: "Why do you think it rains?" and record children's level of understanding.

3. METHODOLOGY

This study uses a theoretical synthesis approach, content analysis and the Delphi method to develop a conceptual framework of scientific competence in preschool education. This approach allows for the collection of information from various sources, while incorporating expert opinions to ensure the reliability and applicability of the scientific competence framework.

3.1. Research design

This study used a mixed research design to identify and develop a conceptual framework for science competencies in preschool education. Specifically, three main methods were applied: 1) Literature Review: Reviewing previous studies on science competencies, STEM education, and assessing science competencies in preschools. 2) Content Analysis: Evaluating current preschool education programs to identify elements that are consistent with the science competency framework. 3) Delphi Method: Collecting expert opinions to identify core components of science competencies in preschool education.

The research was conducted in three main phases: Phase 1: Review of documents on scientific competence and analysis of preschool education programs. Phase 2: Proposing a framework of scientific competence for preschool children. Phase 3: Conducting expert interviews using the Delphi method to collect opinions on the components of scientific competence for preschool children.

3.2. Data collection method

Data were collected from previous studies on: PISA, OECD and NRC science competency frameworks. Preschool science education programs in the world and in Vietnam. Models of science competency assessment and science teaching methods in preschools.

The study conducted expert interviews using the Delphi method to collect opinions on the scientific competency framework for preschool children. The use of the Delphi method helps ensure objectivity and minimize bias in the data collection process (Okoli & Pawlowski, 2004).

3.3. Data analysis method

After collecting data from literature review and expert interviews, the study applied qualitative analysis to identify general trends and draw conclusions. Content analysis was used to identify key themes in the collected data, including: 1) Key components of scientific competence. 2) Approaches to science education in preschool. 3) Criteria for assessing scientific competence suitable for young children.

After synthesizing opinions from experts, the study used the Delphi method to determine the importance of each component in the scientific competency framework. Data from the Delphi rounds were analyzed using descriptive statistics, using medians and interquartile ranges to assess the level of consensus among experts. Criteria with a consensus level of more than 75% were included in the final scientific competency framework. Criteria with a lower consensus level were reconsidered in the next Delphi round or eliminated. This method helps ensure that the scientific competency framework is built on reliable expert opinions and accurately reflects the practice of preschool education.

4. RESULTS

4.1. Scientific competency framework for preschool children

The Science Competency Framework for Preschool Children is built on five main components, reflecting important aspects of scientific thinking and scientific practice skills. Each component includes specific assessment criteria, helping teachers to monitor children's development through learning activities and practical experiences.

Table: Structure of scientific competency framework for preschool children

STT	Capacity	Criteria	Detailed description	Illustrative example
1	Critical Thinking	Identify similarities and differences between objects and phenomena	Children can compare two or more objects and phenomena based on observable characteristics.	Children notice that leaves have different shapes and colors.
		Make inferences based on actual observations	Children can make assumptions or inferences from what they observe.	Children say: "If it is cloudy, it might rain."
		Analyze the causes of a simple phenomenon	Children can find cause-effect relationships from observation.	Children commented: "Fire can evaporate water"
2	Experimental Thinking	Make predictions before testing	Children can predict the outcome of a simple science experiment.	Children guess: "If you mix red with blue, you will get purple"
		Perform simple testing operations	Children actively participate in small science experiments with teacher guidance.	Children put objects in water to test which ones float and which ones sink.
		Draw conclusions from observations	Children can synthesize what they have tested to make comments.	Children say: "Ice will melt when left outside"
3	Observation Skills	Identify and describe the characteristics of objects and phenomena	Children can describe the color, shape, size, and characteristics of objects.	Children describe: "White clouds are light, while black clouds are heavy and signal that it is about to rain."
		Track changes over time	Children can observe the process of change of objects and phenomena.	Children follow the growth of plants from seed to sapling.
		Make comments based on observations	Children can express what they see logically.	Children say: "The sun rises in the morning and sets in the evening"
4	Questioning skills (*Questioning Skills*)	Ask questions about natural phenomena	Children actively ask questions to learn about the world around them.	"Why do leaves change color in fall?"
		Show curiosity about how the world works	Children ask questions about how things work.	"Why do ants walk in lines?"
		Ask about the causes and effects of a change	Children can relate the cause and effect of a phenomenon.	"Can plants live without water?"
5	Problem - Solving *Skills*	Offer different options to solve the problem	Children experiment with different approaches to find the best solution.	Children find ways to keep their dolls from getting wet while playing in the rain.
		Adjust your approach if the initial approach fails.	Children can change strategies when the first approach doesn't work.	Children experiment with different ways to make paper bridges stronger.
		Lessons learned from the testing process	Children can synthesize experiences to apply to other situations.	Children realize: "For plants to grow well, they need light and water."

This scientific competency framework helps children develop scientific thinking early, encouraging exploration, experimentation and questioning. This is not only the foundation for future STEM education but also helps children develop critical thinking, problem solving and adapting to the living environment.

4.2. Using the Delphi method to evaluate the scientific competency framework for preschool children

4.2.1. Description of the survey process

1) Objectives of the Delphi method in this study

Determine the suitability of the components of the scientific competency framework with the developmental characteristics of preschool children.

- Assess the feasibility of applying the competency framework into preschool education practice.
- Reach consensus on criteria for assessing children's scientific abilities.
- Adjust and improve the competency framework based on expert feedback.

2) Criteria for selecting experts

This study invited 15 experts who are excellent teachers with many years of experience teaching preschool children, preschool education managers, and preschool education researchers, specifically as follows:

- Preschool education experts (teachers, education managers) – 7 people.
- Researcher on science education in preschool – 5 people.
- Preschool education program evaluation experts – 3 people.

Experts are selected based on the following criteria: Have at least 5 years of experience in preschool education or educational science research. Have research or teaching practice related to scientific education or children's competency assessment.

3) Delphi method implementation process

The study used three rounds of Delphi to collect and synthesize expert opinions.

Delphi Round	Target	Data collection method	Expected results
Round 1	Collect preliminary comments on the scientific competency framework.	Open survey, experts give qualitative feedback.	Identify key components of scientific capacity that need to be retained, adapted, or supplemented.
Round 2	Rate the importance of each component in the competency framework.	Likert survey (scale 1-5).	Determine the level of consensus on the importance of each evaluation criterion.
Round 3	Validate expert consensus on the final version of the competency framework.	Statistical analysis of consensus (>75%).	Completing the official scientific competency framework.

In the second and third rounds, data were analyzed using descriptive statistics, using medians and interquartile ranges (IQRs) to assess expert consensus. Criteria with ≥ 75% consensus were retained in the competency framework, while criteria with lower consensus were either reconsidered in a subsequent Delphi round or eliminated.

4.2.2. Survey results

After three Delphi rounds with the participation of 15 experts in the field of preschool education and science education, the science competency framework for preschool children was evaluated and adjusted to ensure its suitability, feasibility and effectiveness when applied to teaching practice. Below are the specific results of each Delphi round.

1) Delphi round 1 results:

Collecting preliminary opinions on the scientific competency framework. The objectives of Delphi Round 1 were to determine the adequacy of the five key components of the scientific competency framework. To assess the adequacy of the criteria in each component. To propose adjustments or additions to improve the practicality of the competency framework.

After analyzing the feedback from experts, there are some important comments as follows:

Review Topics	Feedback from experts	Consensus rate (%)	Corrective action
The suitability of the five main components	The five components are considered comprehensive and accurately reflect the scientific skills needed for preschool children.	100%	Constant
Critical thinking	Some experts say it needs to be adjusted to be more suitable for young children, avoiding requiring overly complex logical reasoning.	86.7%	Adjust the criteria to emphasize comparison and simple analysis.
Experimental thinking	Highly regarded because preschoolers learn best through experimentation.	93.3%	Keep it the same
Observation skills	Considered a fundamental element that needs to be maintained.	100%	Keep it the same
Questioning skills	It is considered necessary but needs to clarify how it is actually assessed.	93.3%	Add assessment instructions based on child questions.
Problem solving skills	Some experts suggest extending the scope to practical situations such as environmental care.	80%	Add elements relevant to real-life situations.

The results showed that 100% of experts agreed that the scientific competency framework should focus on five main components: Critical thinking, Experimental thinking, Observation skills, Questioning skills, Problem solving skills. 86.7% of experts said that the criterion "Critical thinking" should be adjusted to better suit the perception of preschool children, emphasizing the ability to compare and analyze simply instead of complex logical reasoning. 80% of experts proposed expanding the criterion "Problem solving skills", adding more real-life situations related to the environment around children. 93.3% of experts said that "Questioning skills" is an important factor, but there needs to be clear guidance so that teachers can observe and evaluate effectively.

Based on this feedback, the study adjusted the competency framework as follows: Adjusted the description of the Critical Thinking criteria, emphasizing comparison and simple analysis instead of complex logical reasoning. Added real-life situational elements in problem-solving skills, helping children apply knowledge to their surrounding environment. Provided assessment guidelines for Questioning Skills through observing the level of curiosity and number of questions children asked during scientific activities.

2) Delphi round 2 results: Assessing the importance of each criterion

The objective of Delphi round 2 is to determine the importance of each component in the scientific competency framework. Evaluate the appropriateness of each evaluation criterion. Eliminate or adjust criteria that do not achieve a high level of consensus.

Experts were asked to rate the importance of each criterion on a 5-point Likert scale (1: Not important – 5: Very important). The results of the statistical analysis are presented in the table below:

Criteria	Median	Interquartile Range (IQR)	Consensus (%)
Critical thinking	4.5	1.0	86.7%
Experimental thinking	4.8	0.5	93.3%
Observation skills	5.0	0.5	100%
Questioning skills	4.7	0.5	93.3%
Problem solving skills	4.6	0.7	80.0%

From the survey results in Delphi round 2, we found that no criteria were eliminated because all reached a consensus level of >80%. Some criteria were re-described for clarity in the evaluation process.

3) Delphi round 3 results: Expert consensus testing

The third round focused on validating expert consensus on the final version of the scientific competencies framework, following adjustments from the previous two rounds. The results showed that 100% of experts agreed with the final version of the competency framework, confirming that the criteria have been adjusted to suit the cognitive characteristics of preschool children. 86.7% of experts assessed that the competency framework can be applied immediately to teaching practice, without requiring major changes in the current education program. 80% of experts said that there should be supplementary guidance documents to help teachers easily implement the competency framework in preschool classrooms. Based on this feedback, the study makes the following recommendations: Maintain the revised competency framework from round 2. Develop detailed instructions on scientific competency assessment methods, providing teachers with tools to effectively observe and record children's development. Thus, after three Delphi rounds, the scientific competency framework has been completed and achieved high consensus from experts. The evaluation results show that the scientific competency framework is suitable for the cognitive development characteristics of preschool children. All criteria achieved a consensus level of ≥ 80%, reflecting the high consensus of the expert community. The applicability to teaching practice is high, and can be integrated into the preschool education program without major changes. It is necessary to supplement the guidance documents to support teachers in more effective implementation.

5. DISCUSSION AND CONCLUSION

This study proposes a scientific competency framework tailored for Vietnamese preschool children, comprising five key components: critical thinking, experimental thinking, observation, questioning, and problem-solving. Developed through literature review and expert consultation via the Delphi method, the framework adapts existing international models, such as PISA and NRC, to suit the developmental needs of preschoolers. Unlike frameworks designed for older learners, this model emphasizes hands-on learning, exploration, and observation, making science more accessible and age-appropriate. A major contribution of the study is offering a structured foundation for integrating science into preschool education, where currently no formal curriculum exists in Viet Nam. This framework not only supports teachers in organizing and assessing scientific activities but also fosters children's early engagement with scientific thinking—laying the groundwork for future STEM learning.

Despite its strengths, the framework has limitations. It has not yet been tested in diverse classroom settings, lacks differentiation by age group, and may require adaptation for varying regional resources. Future research should focus on piloting the framework in practice, developing age-specific guidelines, and evaluating its applicability across different educational contexts. Overall, the study offers a significant step toward systematic and effective science education for young children in Viet Nam.

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