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Application of Knowledge and Skills Competency of Elementary School Students in Science Subject in Vietnam

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Abstract

In Vietnam's 2018 General Education Program for Science, the applied knowledge and skills competency is one of the three components of natural scientific competency (Ministry of Education and Training, 2018a). The applied knowledge and skills competency refers to learners' ability to comprehensively mobilize acquired knowledge and skills and apply them to effectively identify and solve real-world problems in specific contexts. The implementation of the Science subject in elementary schools currently reveals that, although the curriculum includes descriptions of indicators for this competency, and teachers have employed several measures to develop it, the absence of a competency framework with specific competency components and behavioral indicators makes it challenging for teachers to select teaching strategies and effectively assess students' competency development. This study employs the PRISMA systematic review method and benchmarking method to identify the overlapping indicators of the applied knowledge and skills competency in Science subject of the Vietnam’s General Education Program and the scientific competency frameworks of PISA and several other countries. Based on this analysis, a competency framework for applying knowledge and skills in Science appropriate for Vietnamese elementary students was proposed. The proposed framework was refined through expert consultation using the Delphi method and consists of five components and twelve competency indicators.

Keywords: Competency, Application of knowledge and skills, Science subject, Elementary school.

INTRODUCTION

Vietnam's 2018 General Education Program (GEP) transitions from a content-based instruction approach to a competency-based education approach. The curriculum's goal is to "*enable students to master general knowledge, effectively apply learned knowledge and skills in life, and engage in lifelong learning...*" (Ministry of Education and Training, 2018b). According to this goal, the ultimate aim of the education process is for students to apply their acquired knowledge and skills to identify problems, find appropriate solutions, and effectively address real-world issues.

Vietnam's elementary school Science curriculum identifies the applied knowledge and skills competency as one of the three components of natural scientific competency (Ministry of Education and Training, 2018a). The applied knowledge and skills competency includes several indicators: Explaining certain objects, phenomena, and relationships in nature, as well as aspects of the living world, including humans, and health-preserving measures; Solving simple real-world problems by applying scientific knowledge and interdisciplinary skills; Analyzing situations to determine appropriate responses in health-related scenarios involving oneself, their family, their community, and the surrounding natural environment; Engaging in discussions, sharing knowledge, and encouraging others to take action; Evaluating approaches to problem-solving and decision-making in real-life contexts (Ministry of Education and Training, 2018a). This competency is regarded as a fundamental component of the Science subject. Recent studies indicate a lack of consensus and limited research on a competency framework for applying knowledge and skills in Science, including its components and specific behavioral indicators. For instance, according to PISA 2018, student scientific competency framework include these competencies: explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically (OECD, 2019). Meanwhile, Koballa and Glynn (2013) emphasize concepts, attitudes, and motivation in science learning. Hackling and Prain (2008) highlight scientific knowledge, the application of scientific knowledge in everyday life, scientific inquiry competency, and students' positive attitudes toward science as the foundation of scientific competency. Purkat and Devetak (2023) define scientific competency as comprising knowledge, skills, and attitudes toward science. Hue et al. (2024) focus on students' scientific competency within STEM education. As a result, challenges remain in teaching and assessing this competency and selecting appropriate instructional strategies to maximize student competency development in Science.

Using the proposed research methods, this study focuses on developing a competency framework for students' application of their knowledge and skills in Science subject in Vietnam's elementary schools. The goal is to enhance the effectiveness of the development of this competency in the teaching of the subject.

METHODS

Prisma systematic review

The PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was first introduced in 2009 to standardize the reporting process for systematic reviews and meta-analyses. In 2020, PRISMA was updated to reflect advancements in methodology and provide new reporting guidelines for studies (Page et al., 2021). This method is widely used to conduct systematic reviews in educational research, offering a structured approach to ensure objectivity and reproducibility (Chiotaki et al., 2023; Serrano et al., 2022). It has been applied to a variety of educational topics, such as adaptive game-based learning (Chiotaki et al., 2023), immersive virtual reality in foreign language education (Peixoto et al., 2021), and research methods in teaching and learning (Matos et al., 2023). PRISMA-based reviews typically include keyword-based retrieval, study scope definition, result filtering, and grouping and analysis (Chiotaki et al., 2023). When applied correctly, PRISMA enables researchers to address educational questions in an objective and reliable manner (Serrano et al., 2022).

This study employed the PRISMA systematic review method to synthesize and analyze studies related to competency of Science subject and students' applied knowledge and skills competency in elementary school Science subject. Based on this analysis, the study identified key issues to be inherited, supplemented, and further developed. The review was conducted in three phases: identification, screening, and inclusion. The PRISMA flow diagram illustrating these phases is shown in Figure 1.

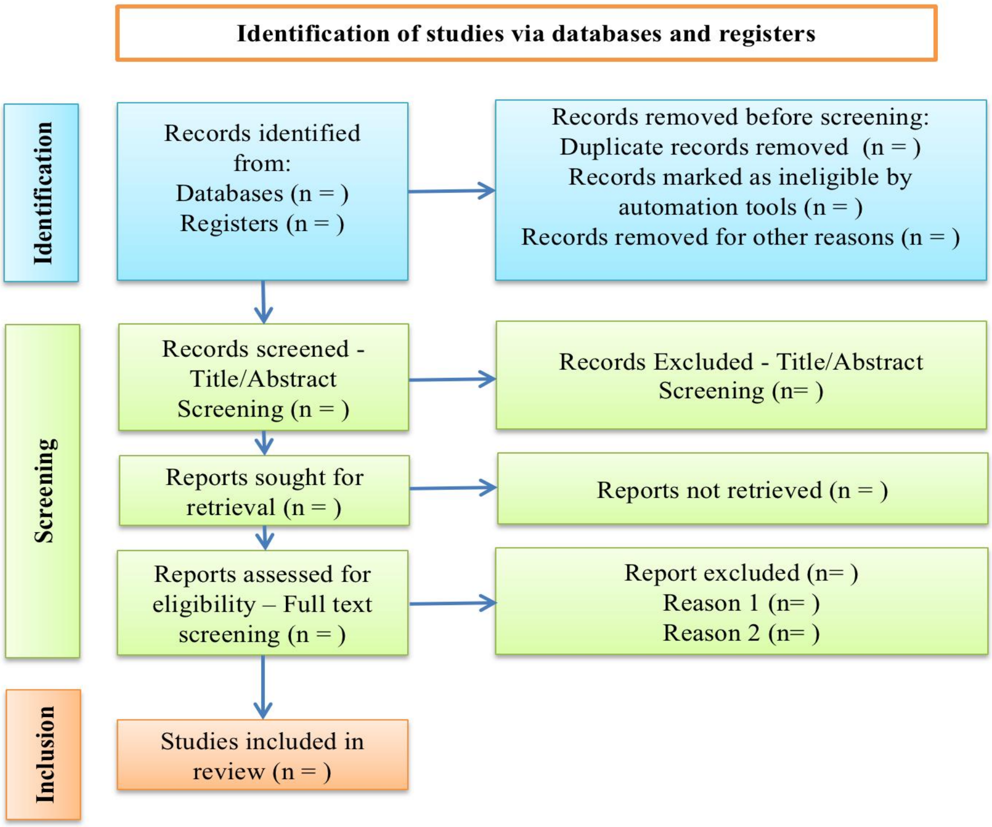

Figure 1. PRISMA flow diagram

Benchmarking:

The benchmarking method in educational research is used to compare two or more entities (such as countries, educational systems, curricula, teaching methods, etc.) to identify similarities and differences, thereby drawing applicable rules, trends, or lessons learned. In 1817, Jullien laid the foundation for comparative education by advocating for the development of a scientific method to compare educational systems across countries (Lenhart, 2018). This method has been increasingly developed and applied in the field of education, with international organizations such as UNESCO, OECD, and IEA employing benchmarking to conduct comparative studies of student performance (e.g., PISA, TIMSS).

Expert consultation (Delphi)

Based on the proposed competency framework for applied knowledge and skills competency in Science subject which is developed through the PRISMA systematic review and benchmarking of competency indicators from Vietnam's GEP against the science frameworks of PISA and several other countries, the study proceeded to use the Delphi method to consult experts and refine the framework.

Delphi method is a widely used and effective qualitative research approach in social sciences and interdisciplinary fields. This method is particularly well-suited for synthesizing in-depth knowledge within a specific domain and helps in finding answers to research questions. In 1963, Dalkey and Helmer introduced the Delphi method, which is characterized by four key characteristics: Anonymity, iteration, controlled feedback, and statistical aggregation of a group response (Linstone and Turoff, 1975).

Most researchers have adopted, either wholly or partially, the definition of Linstone and Turoff (1975) for the Delphi method, describing it as a structured approach to facilitating group communication that enables a group of individuals to collectively solve a complex problem. Studies have shown that the number of discussion rounds can vary—typically two or three rounds, but it may also be more or, in some cases, just one round. The number of participating experts is not fixed and can range from a few individuals to several hundred experts (Skulmoski et al., 2007). The selection of appropriate experts is crucial, as the quality of discussions and contributions directly depends on the expertise and competence of the experts.

During the Delphi process, data can be analyzed using both qualitative and quantitative methods. Open-ended questions are typically used in the initial round to gather expert opinions, while subsequent rounds aim to refine these responses and reach consensus among participants. The level of consensus can be measured using various statistical methods, such as median, mean values, or percentage of agreement, among others. Specific agreement thresholds depend on the Likert scale used: 70% or higher for a 4-point scale, 75% or higher for a 5-point Likert scale, and 80% or higher for a 7-point Likert scale (Hsu & Sandford, 2007).

To synthesize and analyze the results of expert consultation, The KAMET principle (Knowledge Acquisition for Multiple Experts with Time Scales) is used to determine the importance of each criterion (qi) at different stages (see Table 1). This is based on a combination of statistical measures, including rating mean (qi), interquartile range (Q), and rating variant (%). It is important to note that a variant in this context refers to the percentage of experts who change their ratings (Chu & Hwang, 2008). Questions are removed from the survey and further expert consultation is no longer required upon either of the following conditions: (i) Consensus is not reached or (ii) The question is deemed unimportant and eliminated from the survey.

Table 1. Rules for analyzing the ratings from multiple experts with Delphi method and KAMET

Round t	Round t+1	Round t+2
Rating_Mean (qi) ≥ 3.5	IF Rating_Mean(qi) ≥ 3.5 and Q ≤ 0.5 and Rating_Variant(qi) < 15% Then qi is accepted, and no further discussion concerning qi is needed	
Rating_Mean(qi) < 3.5	Rating_Mean(qi) ≥ 3.5 or Rating_Variant(qi) > 15%. Then, proceed with Round t+2.	If Rating_Mean(qi) ≥ 3.5 and Q ≤ 0.5 and Rating_Variant(qi) ≤ 15% Then qi is accepted, and no further discussion concerning qi is needed
Rating_Mean(qi) < 3.5	IF Rating_Mean(qi) < 3.5 and Q ≤ 0.5 and Rating_Variant(qi) ≤ 15%. Then qi is rejected, and no further discussion concerning qi is needed	

However, the KAMET principle can be flexibly adjusted depending on the study and the scale used (3-point, 4-point, 5-point, 7-point, or 10-point scales). The interquartile range (Q) value can be modified accordingly to reflect the level of consensus within a specific research context. For a 5-point Likert scale, each level represents a distinct opinion, and the intervals between levels are relatively small. If Q ≤ 0.5 is applied to this scale, it would require most responses to be identical (e.g., all experts selecting level 4). This strict threshold could result in unrealistic consensus expectations, even when expert ratings differ only slightly. Consequently, this may lead to unnecessary iterations in the Delphi process, forcing experts to continuously adjust their ratings. For a 5-point Likert scale, Q ≤ 1 is a widely accepted threshold in many Delphi studies. When IQR ≤ 1, expert opinions tend to cluster within one or two adjacent levels, indicating that ratings are not overly dispersed (Raskin, 1994; Rayens & Hahn, 2000; Von der Gracht, 2012).

RESULTS AND DISCUSSION

Development process of the competency framework for students' application of knowledge and skills in elementary school Science in Vietnam

The development of the competency framework competency framework for students' application of knowledge and skills in elementary school Science was carried out through a five-step process, as illustrated in Figure 2.

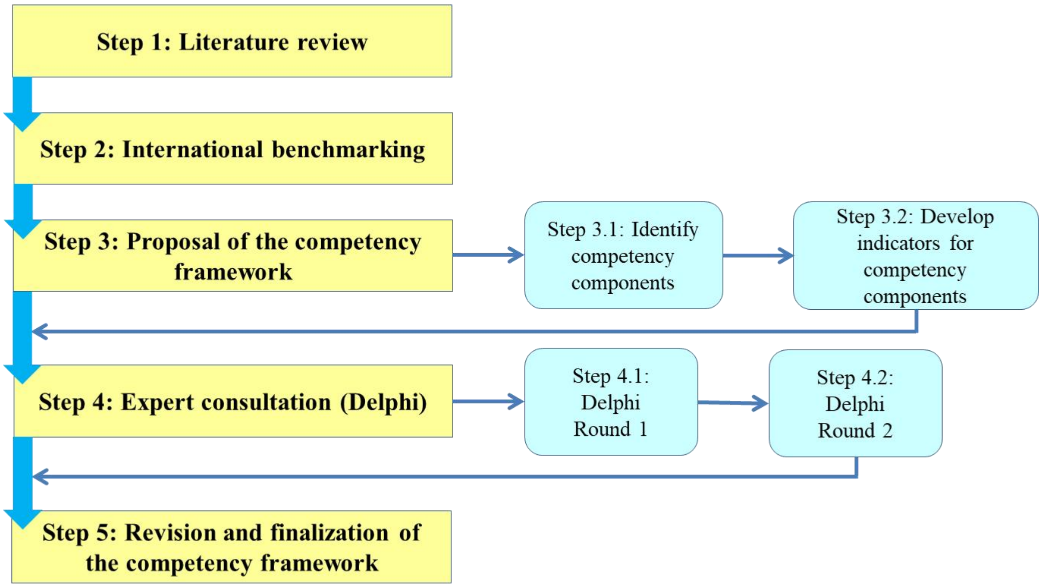

Figure 2. Competency framework for students' application of knowledge and skills in elementary school Science in Vietnam

Overview of research on students' application of knowledge and skills in elementary school Science

A literature review on students' application of knowledge and skills in Science reveals that Vietnam's approach shares similarities with certain aspects of natural science competency and scientific competency. Therefore, this study approaches the appliedknowledge and skills competency in Science as both a natural science competency and a scientific competency.

Scientific competency enables students to understand, evaluate, and process information thoughtfully in daily life (Kutlu-Abu et al., 2023), while also fostering problem-solving skills through hypothesis formulation, experimentation, and analysis (Wilcox & Lewandowski, 2016). This competency further encourages curiosity, exploration, and the development of communication and collaboration skills (Letina, 2020; Purkat & Devetak, 2023). In addition, scientific competency equips students with the ability to distinguish accurate from misleading information in this information-saturated era (Hartman & Nelson, 2016), cultivates creative thinking through the design of experiments and scientific models (Bao et al., 2008), and lays the foundation for lifelong learning (Vieira & Tenreiro-Vieira, 2016)

Scientific competency is a concept being emphasized in many elementary education programs worldwide. According to the Organisation for Economic Co-operation and Development (OECD), within the framework of PISA, scientific competency is defined as "*the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. It includes the ability to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically*" (OECD, 2019). In the United States, the Next Generation Science Standards (NGSS) do not provide a specific definition of scientific competency but emphasize three key dimensions in science learning: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (NGSS Lead States, 2013). The National Research Council (NRC) offers a similar definition, highlighting that scientific competency involves knowledge and understanding necessary for personal decision-making, civic participation, and success in the workplace (National Research Council et al., 1995). In Singapore, the Primary Science Syllabus aims to develop students' scientific inquiry skills such as observation, questioning, planning investigations, analyzing data, and communicating results. It also emphasizes nurturing scientific traits such as curiosity, perseverance, and open-mindedness (Ministry of Education Singapore, 2014). Meanwhile, Japan's elementary curriculum, issued by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), stresses the development of scientific understanding through hands-on experience and exploration, helping students form a foundation for scientific thinking and global citizenship (MEXT, 2017). In Australia's primary curriculum, scientific competency is understood as students' ability to use scientific knowledge and inquiry skills to explore and explain natural phenomena, thereby making responsible decisions based on scientific evidence. This competency is developed through three key strands: Science Understanding, Science Inquiry Skills, and Science as a Human Endeavour (ACARA, 2012). Scientific competency is also embedded as a general capability that contributes to lifelong learning (ACARA, 2012). In South Korea, scientific competency is defined as the ability to solve problems in practical and societal contexts through scientific inquiry, while fostering critical thinking, collaboration, and evidence-based decision-making (Kim et al., 2018; Mullis et al., 2015). Notably, Chiu and Duit (2011) emphasize that in the context of globalization, the concept of scientific competency should be expanded to help students understand and respond to cross-border and global scientific issues. According to Vietnam's GEP for Science, scientific competency includes three components: understanding natural science, exploring the surrounding natural environment, and applying acquired knowledge and skills (Ministry of Education and Training, 2018a). Specifically, the applied knowledge and skills competency includes the following indicators: explaining certain objects, phenomena, and relationships in nature, including the biological world, humans, and health-preserving measures; solving simple real-world problems by applying scientific knowledge and interdisciplinary skills; analyzing situations and determining appropriate responses in health-related contexts involving oneself, family, community, and the natural environment; discussing, sharing, and encouraging others to take action; and evaluating problem-solving approaches and decision-making in real-life contexts (Ministry of Education and Training, 2018a).

The concept of students' scientific competency has been approached from various perspectives by researchers around the world, reflecting the multidimensional and continually evolving nature of this field in modern education. According to Roberts (2007), scientific competency is defined as the ability to use scientific knowledge to make decisions in personal and social life, emphasizing the role of science as an integral part of being an informed citizen. From a historical and U.S. education perspective, Rudolph (2023) analyzes the role of scientific competency as part of civic education to address modern societal challenges. Kutlu-Abu (2022) finds that there is an increasing number of studies focusing on scientific competency at the elementary level, reflecting an awareness of the role of early education in developing scientific thinking. At the international comparative level, Norambuena-Meléndez, Guerrero, and González-Weil (2023) highlight differences in how scientific competency is approached in the education systems of Bolivia and Chile, and they call for clearer definitions of the concept in educational policy. Similarly, Graham (2024) affirms that scientific competency is a key factor that enables students to understand, evaluate, and engage with social and environmental issues. Kelp et al. (2023) emphasize that the development of scientific competency must be closely linked to society and implemented systematically—from curriculum and pedagogy to assessment. Holbrook and Rannikmae (2009) argue that scientific competency comprises not only scientific knowledge but also critical thinking skills, decision-making ability, and personal values related to science. Elhai (2023) underscores the importance of applying scientific knowledge flexibly and creatively in real-world contexts, rather than merely memorizing information. Astuti et al. (2023) and Harefa (2023) share the view that scientific competency refers to learners' ability to use scientific knowledge to recognize, then explain scientific phenomena, and draw conclusions based on scientific evidence. Harefa also emphasizes that developing scientific competency in elementary school Science education is an essential requirement for modern development. Valladares (2021) and Wen et al. (2020) define scientific competency as the knowledge and understanding that enable individuals to make decisions by comprehending scientific concepts and processes. Wulandari (2016) align their concept of scientific competency with PISA 2015, defining it as the ability to explain, solve problems, and draw scientific conclusions based on scientific evidence. The authors Istyadji & Sauqina (2023) and Listiani (2023) expand the scope to include the competency of understanding the nature of science and scientific citizenship, linking it to the PISA assessment framework. Although their expressions differ, studies by Khanh & Oanh (2016), Hung (2020), Cuc (2021), and Dung (2023) all indicate that the applied knowledge and skills competency is learners' ability to effectively apply acquired knowledge and skills to solve real-world problems. Sharing the same perspective as Hoi & Hang (2018), Hong (2022) argues that students can mobilize related knowledge or explore new knowledge to effectively address real-world problems. In the context of Science education, Quynh et al. (2023) state: *“The competency to apply learned knowledge and skills in elementary school Science can be understood as students’ ability to use the knowledge they have acquired and the skills they have developed to solve problems in hypothetical situations or real life effectively”.* Overall, the research highlights the key characteristic of this competency: the flexible application of learned knowledge and skills to solve real-world problems.

Regarding competency frameworks, in 1996, the United States National Research Council introduced a scientific competency framework for students, which includes: scientific knowledge, practical skills, scientific reasoning, thinking about the natural world, and scientific attitudes. The applied knowledge and skills competency is defined as the ability to propose, implement, and address human life demands and tasks based on the accumulation of experience, knowledge, and skills (The Quebec Education Program, 2005). PISA emphasizes students' ability to apply acquired knowledge to solve real-world problems at the age of 15 (OECD, 2017). According to PISA 2015, scientific competency refers to an individual's ability to solve problems, acquire new knowledge, explain scientific phenomena, and draw conclusions based on evidence related to scientific issues (OECD, 2016). PISA 2018 defines the scientific competency framework with these components: Explaining phenomena scientifically, Evaluating and designing scientific enquiry, and Interpreting data and evidence scientifically (OECD, 2019). The TIMSS program aims to assess and evaluate students' understanding of basic scientific concepts and their ability to think independently about learned problems, particularly for 4th and 8th-grade students (cited in Hoa, 2013). Several studies have explored the structure and frameworks of scientific and natural science competency: Eshach (2006) argues that scientific competency in elementary school students is not limited to theoretical knowledge but also includes the ability to observe, formulate hypotheses, conduct experiments, and engage in scientific reasoning. Koballa & Glynn (2013) highlight concepts, attitudes, and motivation in science learning. Hackling & Prain (2008) suggest that natural science competency for students from grades 3 to 7 is built on scientific knowledge, application of scientific knowledge in real life, scientific inquiry competency, and students' positive attitudes toward science. Nunaki et al. (2020) identify core scientific processing skills, including observation, problem formulation, hypothesis development, measurement, communication, and drawing conclusions. Nasution et al. (2023) argue that a person is considered scientifically knowledgeable if they can (1) Identify scientific phenomena, (2) Independently assess and design scientific knowledge and capabilities, (3) Interpret scientific data and evidence. Purkat & Devetak (2023) define scientific competency as comprising knowledge, skills, and attitudes toward science. Hue et al. (2024) propose a six-component framework for scientific competency in STEM education, including (1) Identifying societal needs and defining scientific problems, (2) Proposing ideas and solutions based on known knowledge and skills, (3) Designing solutions based on proposed ideas, (4) Testing the design, (5) Evaluating and refining the design, (6) Acquiring and assessing the validity of newly acquired knowledge.

Through the Prisma systematic review on the concept and competency framework for students' application of knowledge and skills in elementary school Science, this study identifies the following key points:

- Although there is no uniform terminology across international studies, research that approaches this competency as scientific competency or natural science competency generally equates the applied knowledge and skills competency with practical and applied skills (Astuti et al., 2023; National Research Council et al., 1995; NGSS Lead States, 2013; Ministry of Education Singapore, 2014; ACARA, 2012; Kim et al., 2018; Mullis et al., 2015; Roberts, 2007; Elhai, 2023; Hackling & Prain, 2008; Harefa, 2023; TIMSS, 2015; OECD, 2016, 2017, 2019; The Quebec Education Program, 2005; Valladares, 2021; Wen et al., 2020; Wulandari, 2016; Ministry of Education and Training, 2018b; Kutlu-Abu et al., 2023; Wilcox & Lewandowski, 2016). Studies indicate a high level of consensus regarding key indicators of this competency, such as solving real-world problems (Astuti et al., 2023; Nasution et al., 2023; OECD, 2016, 2017, 2019; The Quebec Education Program, 2005; National Research Council et al., 1995; Kim et al., 2018; Mullis et al., 2015; Ministry of Education Singapore, 2014; ACARA, 2012; Roberts, 2007; Valladares, 2021; Wen et al., 2020; Wulandari et al., 2023; Ministry of Education and Training, 2018b; Kutlu-Abu et al., 2023), and explaining real-world phenomena or issues (Astuti et al., 2023; Hackling & Prain, 2008; Harefa, 2023; Nasution et al., 2023; OECD, 2016, 2017, 2019; The Quebec Education Program, 2005; Kim et al., 2018; Mullis et al., 2015; Ministry of Education Singapore, 2014; ACARA, 2012; Valladares, 2021; Wen et al., 2020; Wulandari et al., 2023; ACARA, 2012; Wulandari & Sari, 2023; Ministry of Education and Training, 2018b). Additionally, students' ability to formulate scientific conclusions is widely recognized indicator (Astuti et al., 2023; Dung, 2023; Harefa, 2023; Nunaki et al., 2020; OECD, 2016, 2019; Wulandari et al., 2023; Wulandari, 2016). These findings suggest that while international studies share common conceptual understandings of this competency, the terminology used may vary.

- In addition to common characteristics and consensus, there are differing perspectives regarding the concept and structure of the applied knowledge and skills competency. For example, some studies emphasize students' thinking processes when encountering scientific issues (National Research Council, 1995; TIMSS; Kutlu-Abu, 2022; Bao et al., 2008), while others focus on students' attitudes toward science (Hackling & Prain, 2008; Koballa & Glynn, 2013; The Quebec Education Program, 2005; Letina, 2020; Purkat & Devetak, 2023). Some research highlights scientific skills such as observation, measurement, and communication

(Ministry of Education Singapore, 2014; Nunaki et al., 2020; Eshach, 2006), critical thinking (Kim et al., 2018; Mullis et al., 2015; Rannikmae, 2009; Vieira & Tenreiro-Vieira, 2016). These differences arise due to variations in context, target groups, and research objectives.

- The applied knowledge and skills competency is one of the three components of scientific competency in certain subjects, as defined in Vietnam's 2018 General Education Program. Due to its clearly defined terminology, research on this competency shows a high degree of consistency in its concept and structure. Its key indicators include the ability to mobilize knowledge and skills, explain and solve problems, and practical applicability.

Comparing Vietnamese students' applied knowledge and skills competency in Science with PISA and other countries

According to Vietnam's 2018 General Education Program, the subject-specific competency in Science consists of three components: natural scientific awareness, exploration of the natural environment, and application of acquired knowledge and skills. The Table 2 is a comparative analysis of the indicators of the applied knowledge and skills competency in Science in Vietnam, PISA, Singapore, and Australia.

Table 2. Comparative analysis of the competency components of application of knowledge and skills

Vietnam	PISA	Singapore	Australia
Competency components			
Application of acquired knowledge and skills	Explain phenomena scientifically	- Skills and processes - Ethics and attitudes	Science as a human endeavor
Indicator of competency components			
- Explaining certain objects, phenomena, and relationships in nature, including the living world and human beings, as well as health-preserving measures. - Solving simple real-world problems by applying scientific knowledge and interdisciplinary skills. - Analyzing	*Identifying, proposing, and evaluating explanations for a range of natural and technological phenomena* - Recalling and applying relevant scientific knowledge. - Identifying and using models to explain and	*Skills:* - Reasoning - Hypothesis formation - Prediction - Analysis - Creating possibilities - Evaluation *Processes:* - Solving problems creatively - Making decisions *Attitudes and social*	- Nature and development of science: Facilitating students' high appreciation for the unique nature of science and scientific knowledge, including how knowledge evolves over time through collective human actions. - Using and influencing science: Exploring

Vietnam	PISA	Singapore	Australia
situations to determine appropriate responses to health-related scenarios involving oneself, their family, their community, and the surrounding natural environment; engaging in discussions, sharing, and encouraging others to take action. - Evaluating problem-solving approaches and decision-making in real-life contexts.	predict phenomena. - Making appropriate predictions. - Developing explanatory theories. - Explaining the potential impacts of scientific knowledge on society.	*responsibility*: - Curiosity - Creativity - Integrity - Objectivity - Open-mindedness - Perseverance - Responsibility	how scientific knowledge is applied and its impact on life and society, and how science can be used to inform decisions and actions.

Vietnam's 2018 GEP for Science not only expects students to apply the subject's knowledge and skills to analyze, evaluate solutions, and explain and solve real-world problems, but also emphasizes their ability to integrate knowledge and skills from related subjects to address real-life challenges. Additionally, the curriculum aims to foster appropriate attitudes toward nature, environmental responsibility, and public health protection (Ministry of Education and Training, 2018b). In the PISA competency framework, the application of knowledge and skills is reflected in the ability to explain natural and technological phenomena. PISA primarily focuses on students' ability to apply knowledge to explain real-world phenomena through activities such as utilizing knowledge, using models, proposing hypotheses, and explaining phenomena (OECD, 2019). In Singapore's Science curriculum, the students' application of knowledge and skills is categorized under the component of process (part of the skills and processes domain) and includes problem-solving and decision-making. Additionally, the curriculum places strong emphasis on students' attitudes and responsibilities when learning Science, highlighting traits such as curiosity, creativity, integrity, objectivity, open-mindedness, perseverance, and responsibility (Ministry of Education, Singapore, 2014). However, specific expectations regarding the application of knowledge and skills in real-world contexts are not explicitly outlined. In Australia, besides requiring students to solve real-world problems, the curriculum also expects them to understand how scientific knowledge evolves in response to changing realities and how science influences and is influenced by society (ACARA, 2012)

Thus, through the comparative analysis, it can be observed that although there is no complete alignment, there are similarities in the indicators of the applied knowledge and skills competency in Science between Vietnam, PISA, Singapore, and Australia. These similarities include students' ability to apply scientific knowledge and skills to explain and solve real-world problems while demonstrating appropriate attitudes toward practical issues.

Proposed competency framework for students' application of knowledge and skills in elementary school Science in Vietnam

In this study, we propose the following definition of the elementary students' applied knowledge and skills competency in Science: "*the ability of learners to mobilize and comprehensively apply acquired knowledge and skills to identify and effectively solve real-world natural science-related problems while demonstrating appropriate attitudes and responses*".

Based on the Prisma systematic review, benchmarking with PISA, Singapore, and Australia, this paper proposes a competency framework for students' application of knowledge and skills in elementary school Science in Vietnam, as described in Table 3.

Table 3. Competency framework for students' application of knowledge and skills in elementary school Science in Vietnam

Code	Competency component	Indicator
A1	Identifying problems based on scientific knowledge	A1.1: Asking questions about natural science problems. A1.2: Analyzing the identified problem. A1.3: Recognizing scientific problems that need to be solved.
A2	Connecting and mobilizing relevant knowledge and skills	A2.1: Identifying the knowledge and skills that Science subject needs to apply to solve the problem. A2.2: Identifying the scientific knowledge and skills that other relevant subjects need to apply to solve the problem. A2.3: Exploring new knowledge necessary for problem-solving.
A3	Proposing solutions based on scientific knowledge and interdisciplinary subjects	A3.1: Proposing solutions based on acquired knowledge and skills. A3.2: Selecting the optimal solution. A3.3: Planning the implementation of the solution.
A4	Solving problems based on scientific knowledge	A4.1: Explaining a number of objects, phenomena, and relationships in natural science.

Code	Competency component	Indicator
	and interdisciplinary subjects	A4.2: Solving real-world scientific problems. A4.3: Responding appropriately to real-world scientific issues.
A5	Reviewing and evaluating the application outcomes	A5.1: Reviewing and evaluating the effectiveness of the implemented solution. A5.2: Identifying lessons learned from applying knowledge and skills. A5.3: Discovering new relevant problems

Expert consultation results on the competency framework for students' application of knowledge and skills in elementary school Science

Experts participating in the survey:

The study invited experts from the following groups: Researchers with in-depth knowledge of general education, Science education, and STEM education for elementary schools; Experts with experience in developing the elementary school Science curriculum; Authors of Science textbooks; Lecturers teaching theoretical and methodological courses on Natural and Social Sciences/Science education at universities that train elementary school teachers; Elementary school management staff and teachers with hands-on experience in teaching and assessing Science learning in elementary education.

- Round 1: The study sent invitations to 65 experts and received 60 confirmations of participation, including: 02 educational researchers with extensive publications on general education, Science education, and STEM education for elementary schools, who had contributed to developing the elementary school curriculum; 12 university lecturers teaching elementary education students, with experience in research, Science textbook writing, and training elementary school teachers in teaching and assessment methods for Science; 07 elementary school management staff and 39 elementary school teachers with hands-on experience in teaching and assessing Science learning in elementary education. The expert panel members were only identifiable by assigned codes, and their personal information was kept strictly confidential. The researchers explicitly stated this confidentiality commitment in the invitation letter sent to all experts.

- Round 2: To enhance the reliability of the interview results and to allow experts with extensive knowledge and years of experience in the field to reach a consensus on differing viewpoints from Round 1, we invited 47 experts from Round 1 who had a minimum of five years of experience to participate in the second survey round. A total of 45 experts agreed to continue (accounting for 75% of the participants from Round 1). The experience, qualifications, and professional roles of the experts participating in both survey rounds are detailed in Table 4.

Table 4. Experience, qualifications and professional roles of the experts participating in the survey

Sample		Experience			Qualification			Professional role			
		< 5 years	5-10 years	>10 years	Ba-chelor	Mas-ter	Doc-tor	Re-searcher	Lec-turer	Manage-ment staff	Tea-cher
Round 1 (n=60)	Quan-tity Ratio (%)	13 21.7 %	19 31.7 %	28 46.7 %	33 55.0%	14 23.3 %	13 21.7 %	2 3.3%	12 20.0%	7 11.7%	39 65.0%
Round 2 (n=45)	Quant ity Ratio (%)	0 0%	17 37.8 %	28 62.2 %	18 40.0%	14 31.1 %	13 28.9 %	2 4.4%	12 26.7%	7 15.6%	24 53.3%

Questionnaire content:

The authors compiled and proposed a competency framework for students' application of knowledge and skills in elementary school Science, consisting of five competency components and fifteen indicators. A questionnaire was developed and distributed to experts via an online survey platform (Google Form). The questionnaire included 20 multiple-choice questions rated on a five-point Likert scale: For competency components, experts rated their relevance from *Not relevant (1)* to *Highly relevant (5).* For indicators, experts rated their importance from *Not important (1)* to *Highly important (5).* Additionally, the questionnaire contained an open-ended section, allowing experts to provide additional feedback, modifications, or corrections. Before being presented for expert group discussion, the questionnaire was reviewed and refined based on feedback from a distinguished researcher with extensive experience in elementary education and competency assessment.

Delphi discussion results:

Round 1: The results of the first-round survey indicate that all competency components had an average score greater than 3.5. Among the 15 indicators, 02/15 indicators had an average score below 3.5, and 03/15 indicators did not achieve a consensus rate of ≥ 75%. Details are presented in Table 5.

Table 5. Data analysis result from round 1

No.	Competency component/indicator code	Round 1 (N=60)		
		Average score	*Consensus rate*	*Interquartile range*
Competency component				
1	A1	4.22	86.7	1.0
2	A2	4.28	88.3	1.0
3	A3	4.18	85.0	1.0
4	A4	4.25	87.2	1.0
5	A5	4.17	94.6	1.0
Indicator				
1	A1.1	4.27	83.3	1.0
2	A1.2	3.47	56.7	1.0
3	A1.3	4.30	95.0	1.0
4	A2.1	4.25	90.1	1.0
5	A2.2	4.22	90.0	1.0
6	A2.3	4.48	51.7	1.0
7	A3.1	4.30	95.0	1.0
8	A3.2	4.22	86.7	1.0
9	A3.3	4.13	85.0	1.0
10	A4.1	4.32	93.3	1.0
11	A4.2	4.27	91.1	1.0
12	A4.3	4.23	88.3	1.0
13	A5.1	4.23	90.0	1.0
14	A5.2	3.60	66.7	1.0
15	A5.3	4.22	91.7	1.0

According to the KAMET principle, we proceeded with Round 2 of the survey to further assess and consider the removal of indicators with an average score below 3.5 or a consensus rate below 75%.

Round 2: The results of Round 2 for the competency framework on students' application of knowledge and skills in elementary school Science indicate a high consensus rate among experts, as shown in Table 6.

Table 6. Experts' consensus on the competency framework for students' application of knowledge and skills in elementary school Science after round 2 of the Delphi study

No.	Competency component/indicator code	Round 2 (N = 45)			
		Average score	*Consensus rate*	*Interquartile range*	*Variance (percentage of experts who change their ratings)*
Competency component					
1	A1	4.20	86.6	1.0	5.0%
2	A2	4.22	86.7	1.0	1.7%
3	A3	4.09	82.3	1.0	6.7%
4	A4	4.23	82.2	1.0	1.7%
5	A5	4.13	86.7	1.0	0.0%
Indicator					

No.	Competency component/indicator code	Round 2 (N = 45)			
		Average score	*Consensus rate*	*Interquartile range*	*Variance (percentage of experts who change their ratings)*
1	A1.1	4.18	93.3	1.0	10.0%
2	A1.2	4.47	57.8	1.0	0.0%
3	A1.3	4.22	93.3	1.0	5.0%
4	A2.1	4.27	93.3	1.0	1.7%
5	A2.2	4.20	91.1	1.0	1.7%
6	A2.3	4.40	48.9	1.0	11.7%
7	A3.1	4.31	95.6	1.0	0.0%
8	A3.2	4.20	84.5	1.0	0.0%
9	A3.3	4.09	82.3	1.0	1.7%
10	A4.1	4.27	93.3	1.0	0.0%
11	A4.2	4.24	91.1	1.0	6.7%
12	A4.3	4.20	86.6	1.0	3.3%
13	A5.1	4.27	88.9	1.0	1.7%
14	A5.2	3.60	66.6	1.0	0.0%
15	A5.3	4.16	88.9	1.0	1.7%

The results of Round 2 indicate that all competency components achieved a high level of consensus.

For the indicators that did not reach consensus in Round 1, following the KAMET principle, indicators A1.2 and A2.3 were eliminated without further consultation, as their average scores remained below 3.5 across both rounds, with $Q \leq 1$, and the variance (percentage of experts changing their ratings) was below 15%. Indicator A5.2, despite having an average score above 3.5, $Q \leq 1$, and variance < 15%, still failed to achieve a consensus rate of ≥ 75% across both rounds, leading to its removal.

Regarding indicators A1.3 and A1.1, since A1.3 consistently received a higher importance score than A1.1 across both rounds, their order was adjusted accordingly.

After two rounds of expert consultation using the Delphi method, experts provided additional feedback and revisions. By the end of Round 2, consensus was reached on the final competency framework, which consists of five competency components and twelve indicators.

Revision and finalization of the competency framework for students' application of knowledge and skills in elementary school Science:

After two rounds of the Delphi method, based on the evaluations and feedback from experts, the study revised and finalized the competency framework for students' application of knowledge and skills in elementary school Science in Vietnam, consisting of five competency components with twelve indicators, as described in Table 7.

Table 7. Competency framework for students' application of knowledge and skills in elementary school Science in Vietnam

Code	Competency component	Indicator
A1	Identifying problems based on scientific knowledge	A1.1: Recognizing scientific problems that need to be solved A1.2: Asking questions about natural science problems
A2	Connecting and mobilizing relevant knowledge and skills	A2.1: Identifying the knowledge and skills that Science subject needs to apply to solve the problem A2.2: Identifying the scientific knowledge and skills that other relevant subjects need to apply to solve the problem
A3	Proposing solutions based on scientific knowledge and interdisciplinary subjects	A3.1: Proposing solutions based on acquired knowledge and skills A3.2: Selecting the optimal solution A3.3: Planning the implementation of the solution
A4	Solving problems based on scientific knowledge and interdisciplinary subjects	A4.1: Explaining a number of objects, phenomena, and relationships in natural science A4.2: Solving real-world scientific problems A4.3: Responding appropriately to real-world scientific issues
A5	Reviewing and evaluating the application outcomes	A5.1: Reviewing and evaluating the effectiveness of the implemented solution A5.2: Discovering new relevant problems

CONCLUSION

The study developed and finalized the competency framework for students' application of knowledge and skills in elementary school Science in Vietnam by integrating multiple research methods, including the Prisma systematic review, benchmarking, and the Delphi method. Initially, the proposed framework consisted of five competency components with fifteen indicators. After two rounds of Delphi consultation, experts reached a high level of consensus on all five competency components. Additionally, after eliminating, reorganizing, and refining certain indicators, the final set of indicators received strong expert consensus. This confirms the framework's alignment with the practical context of Science education for elementary students in Vietnam. The revised and finalized competency framework consists of five competency components: 1) Identifying problems based on scientific knowledge 2) Connecting and mobilizing relevant knowledge and skills 3) Proposing solutions based on scientific knowledge and interdisciplinary subjects 4) Solving problems based on scientific knowledge and interdisciplinary subjects 5) Reviewing and evaluating the application outcomes.

Developing assessment levels and measures to enhance competency to test the applicability of this competency framework in actual Science teaching in elementary schools is a critical direction for future research. Continued efforts in this area shall be promoted to contribute to fostering students' applied knowledge and skills competency in Science, thereby supporting the implementation of Vietnam’s 2018 General Education Program.

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