Design a Framework on Teaching Experimental Practice Competencies in Primary Science Education

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Abstract

This research offers a detailed framework for evaluating the assessing the teaching experiment practice of teachers in science education, specifically within the primary stage of the Vietnamese educational system. The framework development employs sophisticated statistical methods, such as first- and second-order confirmatory factor analysis (CFA), to guarantee a rigorous psychometric evaluation. The approach includes three competence factors: professional knowledge, practical skills, and the capacity to arrange instruction and evaluation. The research findings indicate that the proposed measure satisfies the requirements for internal consistency, reliability, and validity, serving as a helpful instrument for evaluating instructors' teaching practices in scientific education. The study's thorough psychometric assessment enhances the comprehension of experimental practice abilities within the Vietnamese educational sector. The results have ramifications that extend beyond the Vietnamese context and are pertinent to international education. In addition, the study enriches the understanding of measuring teaching experiment practice competencies in the context of science education, providing valuable insights for educators and motivating them in Vietnam and other countries.

Keywords: competencies, experimental practice, primary schools, teaching, teachers

INTRODUCTION

In the new context, socio-economic development has set new educational career requirements. Educa-tion has become a decisive field and a solid foundation for the sustainable development of each country (Quiroz-Niño et al., 2017). Primary education is an essential level in Vietnam's national education sys-tem, with the goal of "help students form and develop basic elements that lay the foundation for harmoni-ous physical and mental development, qualities, and competencies; focusing on education about personal values, family, community, and necessary habits and routines in learning and living" (Ministry of Education and Training, 2018).

Science, a compulsory subject in grades 4 and 5 of the primary school program, builds on the essential, initial foundation of the natural sciences and the research fields of health and environmental education (Ministry of Education and Training, 2018). This subject is critical in helping students learn Natural Sciences at the junior high level and Physics, Chemistry, and Biology at the high school level. It focus-es on arousing scientific curiosity, initially creating opportunities for students to learn and explore the natural world, putting learned knowledge and skills into practice, and learning how to maintain health and behave appropriately with the surrounding environment. Furthermore, Science contributes to the formation and development of general and natural science competencies for primary school students, including the following components: natural science awareness, learning about the surrounding natural environment, and applying learned knowledge and skills (Dung et al., 2024). Furthermore, Science program explicitly emphasizes the importance of "enhancing students' active participation in the learning process. Students learn science through research, discovery, observation, experimentation, practice, and teamwork" (Ministry of Education and Training, 2018).

The implementation of teaching experimental practice marks a transition from a content-oriented approach to qualities and competencies that enhance learners' competency (Dung et al., 2024). It has proven to be highly effective in the educational process, particularly in science teaching, and has gained widespread acceptance worldwide (Ayşe & Böyük, 2012; Yeşilyurt et al., 2020). Teaching experiential practice helps students develop positivity, initiative, and creativity (Hang et al., 2020) and significantly changes their motivation and success in learning science (Sevinc et al., 2011). According to Ly et al. (2018), teachers must develop their teaching experimental practice competencies as an integral part of their teaching competency to meet the requirements of the science program, with a focus on develop-ing learners. Therefore, developing and improving teachers' experiential practice teaching competency is an urgent and critical task (Zhou et al., 2020). Specifically, this issue requires attention to enhance pedagogical competency, improve education and training quality in general, and enhance the effectiveness of teaching and learning activities in experimental practice. However, limited studies have been conducted in Vietnam on the teaching competency of experiential practice. In the aforementioned contexts, the study seeks to investigate the fundamental elements of primary school teachers' experimental practice competency. This endeavor involves constructing a standardized framework for design thinking competency, ensuring reliability and validity to contribute effectively to the assessment process.

The 2018 Science Curriculum guideline in Vietnam

The Vietnamese Ministry of Education and Training (MOET) recently initiated a major educational reform, starting with curriculum reform (Le et al., 2021). The most updated primary school science curriculum guidelines were issued in 2018, shifting from a content-based approach to a competency-based approach (Ha & Duong, 2020). The design aims to enhance students' knowledge, skills, and atti-tudes for executing specific tasks (MOET 2018), prioritizing their abilities over their knowledge (Ha & Duong, 2020).

Basic knowledge of the natural sciences (such as physics, chemistry, biology, ...) and research areas like health education and environmental education form the foundation of primary school science. Accord-ingly, the Science program's educational content includes six topics: matter, energy, plants and animals, humans and health, fungi, bacteria, organisms, and the environment. These topics are developed from grades 4 to 5. Each topic presents the content at a simple and appropriate level, focusing on value education, life skills education, health education, technology, environmental education, biodiversity conservation education, climate change response, disaster risk reduction and prevention, etc. (MOET, 2018)

At present, there are numerous limitations in the documents and regulations guiding experiment pracitce at the primary level, primarily targeting equipment and laboratory staff in junior high and high school settings (Dung et al., 2024). Specifically, the MOET issued Decision No. 2774/QD-BGDDT on "Issuing the training program according to the professional title standards of equipment and experimental officers" with the following specific objectives (i) improve the level of understanding and implementation of the Party's guidelines and policies, the State's laws, regulations and requirements of the sector, intersectoral and local authorities on education in general and equipment and experimental work in particular; (ii) raise awareness of essential knowledge and skills of equipment and experimental work; (iii) improve the effectiveness of the flexible application of knowledge and skills of equipment and experimental work in performing tasks; (iv) improve the quality and effectiveness of equipment and experimental work in schools (MOET, 2023).

Teaching experimental practice in science education

The framework of teaching competency of experimental practice has become one of the necessary standards for teachers in the process of teaching experimental practice, flexibly applied in the assess-ment of teachers' teaching competency of experimental practice, ensuring conformity with the characteristics of each different country (Duit & Treagust, 2003; Furtak et al., 2012). Scientists in Vietnam have studied the theoretical issue of fostering teachers' teaching competency; these studies primarily focus on the innovation of teaching methods, training measures, and proposals for developing training programs that align with the demands of Vietnamese education, thereby enhancing the quality of training and nurturing teachers' teaching competency. Therefore, teachers have shown interest and concen-tration in various aspects, including goals, content, form, and training methods (Ferreira et al., 2020). This is considered a vital task of the education and training sector to continuously improve teachers' teaching competency while creating favorable conditions for all teachers to promptly supplement their knowledge and innovate teaching methods and forms suitable to the practical context of the economy and society.

Measuring teacher's competency

Internationally, teacher assessment methods and tools have received increasing attention due to the growing need for quality assurance and widespread recognition of the teaching profession (Darling-Hammond, 2021). The assessment methods and tools will also differ depending on the various assessment purposes. Specifically, Roelofs & Sanders (2007) have used questionnaires and psychometric tests to assess teacher personality traits and identify desirable or undesirable characteristics. Administering standardized knowledge tests is a frequently used method for assessing teachers' professional knowledge (Copur-Gencturk & Thacker, 2021). In addition, standardized tests and assessments will be implemented to test knowledge related to pedagogical knowledge, such as teaching methods, curriculum development, student grouping, etc. (König et al., 2020). Additionally, researchers have developed numerous observation tools to concentrate on small behavioral units, believed to be associated with successful student learning outcomes (Katz-Buonincontro & Anderson, 2020). In addition, interview methods are also used to assess teachers' competencies. During these interviews, interviewers display video recordings of teachers and ask them questions about their knowledge, skills, and practical teaching experiences, with the assessment centering on their behavior in specific situations (van Braak et al., 2021). On the other hand, assessment tools can also be lesson materials, lesson observations (direct or recorded, focusing on teacher actions or student activities to assess teacher competence), teacher diaries (focusing on teaching actions), reflective interviews (focusing on teacher decision-making processes during teaching), reflective reports, student tests (focusing on outcomes), teacher written tests (focusing on knowledge base, skills, or decision-making processes), multimedia teacher tests (focusing on knowledge base or decision-making processes), etc. (Spruce & Bol, 2015; Dayal, 2021; Orakcı, 2021).

METHOD

Delphi method for item development

This research employed the Delphi approach. This survey methodology employs a blend of qualitative and quantitative approaches, relying on the insights of chosen experts to achieve a collective agreement on a subject (Olsen et al., 2021). Delphi techniques are deemed suitable when scientific information on the subject is limited and advantageous when direct data collecting is unfeasible (Naisola-Ruiter, 2022). A multi-round survey, comprising three rounds, was undertaken over four months to ascertain the essential components of teaching experimental practice competency deemed required by education experts and instructors. A three-round method was employed (Clark et al., 2020; Olsen et al., 2021). The initial round was an open-ended questionnaire soliciting experts' opinions on the competencies pertinent to teaching experimental practice proficiency. This established the basis for a systematic second-round questionnaire. The last round reevaluated the outcomes of the second round to achieve consensus by prioritizing and ranking the recognized capabilities.

Participants

Participants were selected by following citeria: (i) the group be knowledgeable, (ii) able to provide valuable input into the process, (iii) provide diverse perspectives and feedback on all competencies that may be considered necessary for assessing teaching experimental practice competency (Sezgin et al., 2020).

As for the sample size, studies have shown that a Delphi panel typically has fewer than fifty participants (Delbecq et l., 1975). In this study, thirty experts were initially invited to participate in the first round. Twenty-six participants accepted the invitation in the first round. Anonymity is a critical component of Delphi studies, and therefore, the same list of twenty-six experts was emailed for each of the three Delphi rounds. Participants did not know the content of the other responses. After each round, the research team analyzed the results and returned another questionnaire in the next round. Table 1 presents the demographic information of the study sample.

Table 1. Participant Information Participated in Delphi Method

Participants		Number	Frequency (%)
Gender	Male	8	30.77
	Female	18	69.23
Profession	Lecturer in Teacher Education	5	19.23
	Leturer (other)	2	7.70
	Managerial staff	7	26.92
	In-service Teacher	7	26.92
	Pre-service Teacher	5	19.23
Seniority	Under 5 years	10	38.46
	From 5 to 10 years	8	30.77
	From 10 to 15 years	5	19.23
	Over 15 years	3	11.54

Measurement

The questionnaire for the first round consisted of five questions, the first seeking demographic information (gender) and the second seeking professional qualifications and current professional work. The final question asked, "What core competencies do you believe are essential for assessing teachers' practical teaching competence in elementary science?" and asked respondents to describe each competency briefly. The questionnaire was pre-tested by three experts in the field of teacher education. For the second round, a structured questionnaire was designed based on the results of the first round and sent to the original list of invited participants. The questionnaire began with three questions that sought demographic information. Then, the competencies were listed, and respondents were asked to rate them on a 5-point semantic scale of importance, with 1 being "not at all important" and 5 being "very important." Additionally, an open-ended question was included to allow participants the space to add any potential competencies that, upon reflection, they found needed to be added to the list.

A second-round analysis yielded a revised list of competencies that formed the basis for the instrument submitted in round three. The third and final round of the Delphi asked participants to rank the compe-tency components in order of importance.

Data analysis

Data from the second round were inputted and analyzed utilizing SPSS statistical software (version 26.0; SPSS Inc., Chicago, IL, USA). Median values and frequency distributions were computed to assess the degree of consensus about each ability. Competencies were deemed to have reached consensus on their significance if they received a rating of ≥ 5 from over 50% of respondents and had a median score of ≥ 5 (Moynihan et al., 2015). The median was employed in the second round to assess central tendency due to the non-normal distribution of the data and the limited sample size utilized for the Delphi method. Frequency distributions are commonly employed to evaluate consensus in Delphi investigations, with a threshold of at least 51% answers for every response category established to signify agreement (De Meyer et al., 2019).

During the third session, participants were instructed to identify their top ten competences from the provided list and rank them by significance. Points for each competency were distributed as follows: 10 points for a 1st rank, 9 points for a 2nd rank, and 1 point for a 10th rank. If a competency was not in the top 10, a score of 0 was awarded. The scores for each skill were aggregated, and their average value was computed. The literature study indicates that Delphi studies often utilize arbitrary cut-off values (Jünger et al., 2017). The study's choice to choose a mean value > 2 as a threshold for competency inclusion aligns with a comparable investigation by Kokko et al. (2006).

Scale development and validation

Participants

According to Hair et al. (2019), the sample size for studies with SEM analysis and models with 7 or fewer research concepts is at least 300. The study applied the cumulative random sampling method to collect information from individuals related to the research problem. The study's sampling took place over 3 months through direct and Google survey forms. The results were 914 valid responses; the demographic information of the sample participating in this period is presented in Table 2.

Table 2. Participant Information Participated in Scale Development and Validation

Participants		Number	Frequency (%)
Gender	Male	198	21.7
	Female	716	78.3
Profession	Lecturer in Teacher Education	15	1.6
	Leturer (other)	-	-
	Managerial staff	47	5.2
	In-service Teacher	800	87.53
	Pre-service Teacher	52	5.67
Seniority	Under 5 years	214	23.4
	From 5 to 10 years	75	8.2
	From 10 to 15 years	196	21.4
	Over 15 years	429	46.9

Scale development

Next, quantitative studies with a small sample size will be conducted to preliminarily evaluate the scale of the research concepts. This step's scale evaluation criteria include reliability and scale validity. The criterion of Cronbach's alpha coefficient reaching over 0.7 and the item-total correlation coefficient being more significant than 0.3 assesses reliability (Torkian et al., 2020). The EFA exploratory factor analysis evaluates the convergent value of the scale using the loading factor (FL). When the loading factor threshold reaches a minimum value of 0.5 and the accumulated variance percentage surpasses 50%, the scale attains a convergent value (Sovey et al., 2020). In addition, for each observed variable, the difference between the maximum loading factor and other loading factors (in absolute value) must be 0.3 or more to ensure a discriminant value (Rönkkö, & Cho, 2022). Preliminary analysis at this stage will help reduce the number of behavioral indicators in the competency assessment tool and extract the number of components in the structure of teachers' experimental practice teaching competen-cy.

Scale evalution

Reliability assessment

The scale's internal consistency reliability is assessed using two indices: Cronbach's alpha coefficient and composite reliability (CR) (Devellis & Thorpe, 2021). A higher Cronbach's alpha value signifies increased dependability in terms of internal consistency. A composite dependability score is regarded as satisfactory when it surpasses 0.7 on a scale of 0 to 1.

Convergent and discriminant validity assessment

Convergent validity refers to the degree to which the measured variables of a concept come together or have a shared fraction of variance, necessitating a strong intercorrelation among the measured variables to establish convergence (Kline, 2016). This is demonstrated by the standardized regression coefficients for each variable of the latent idea, assuming it is a unidimensional scale. In order to establish convergent validity, the standardized coefficients of the individual variables in the scale must surpass 0.5 and demonstrate statistical significance (Gerbing & Anderson, 1988). Moreover, in order to establish con-vergent validity, it is necessary for the average variance extracted (AVE) to be equal to or larger than 0.5, as stated by Hair et al. (2019). Discriminant validity is the statistical ability to distinguish one no-tion from another based on the correlation and measurable variables inside each concept (Hair et al., 2019). The conventional method for evaluating discriminant validity is the Fornell-Larcker criteria, which states that the square root of the average variance extracted (AVE) should exceed the interconstruct correlations. Another factor to consider is to make sure that the correlation between two ideas is below 0.85 and that the maximum shared variance (MSV) is lower than the average variance extract-ed (AVE) (Kline, 2016).

RESULTS AND DISCUSSION

Results of content validity correction by using the Delphi method

In the first round, the panel consisted of 30 individuals involved in primary school teacher education, achieving a response rate of 86.67%. Different responses were received from the respondents, the an-swers were categorized accordingly, and 16 component competencies were identified. In the second Deplhi round, the competencies were randomly assigned to the respondents so as not to influence the results. The items presented in Table 2 below are the results from the second round, including the me-dian and frequency distribution of each competency. It can be seen from Table 3 that the competencies all met the condition of ≥ 5 by more than 50% of respondents and achieved a median of ≥ 5. Therefore, the questionnaire was retained and administered to the respondents in the third round. In the final round, the mean score analysis results showed that all competencies met the research condition of a mean value ≥ 2 as a cut-off point.

Table 3. List of Competencies

No.	List of competencies	2nd round		3rd round
		Median	Frequency (%)	Arithmetic mean
A1	Scientific professional knowledge	7	92.3	2.92
A2	Knowledge of theories and methods of teaching experimental practices	6	92.3	4.73
A3	Correctly implement regulations, safety rules and experimental techniques	6	92.4	3.50
A4	Planning scientific experiments	6	80.8	4.19
A5	Selecting tools and chemicals to conduct experiments	6.5	88.5	3.77
A6	Conducting experiments safely, with reasonable operations, clear and observable phenomena	6	80.8	3.15
A7	Describing experimental phenomena, applying theoretical content to explain experimental phenomena	6.5	88.5	3.15
A8	Selecting experiments that are appropriate to the teaching objectives and student subjects	6	84.7	3.16
A9	Using experiments in combination with active teaching methods	6	88.5	2.62
A10	Asking questions to guide students to observe phenomena to draw conclusions	6.5	92.3	3.19
A11	Handling situations and guiding students to practice experiments	6.5	84.6	2.50
A12	Applying active testing and evaluation methods	6	84.7	3.42
A13	Building a framework for testing and evaluating experimental practice results	6	80.8	3.81
A14	Organizing students to self-test, evaluate and peer-evaluate	6	88.5	3.58
A15	Applying information technology in testing and evaluating experimental practice results	6	80.8	3.12
A16	Using test and evaluation results to adjust teaching plans	6	84.6	3.96

Preliminary assessment of reliability and validity of the scale

The analysis of the sample distribution, as presented in Table 4, demonstrated that the sample conforms to the standard of normal distribution, as evidenced by the approximate equality of mean and median values, absolute skewness values below 2 (the maximum being |skewness (A1)| = 1.36), and absolute kurtosis values below 2 (the maximum being |kurtosis (A3)| = 1.73) (Dash & Paul, 2021).

Table 4. Results of Testing The Distribution of the Research Sample

Behaviour indicator	Mean	Median	Mode	Standard deviation	Skewness	Kurrtosis
A1	5.99	6.00	7.00	1.26	-1.36	0.60
A2	6.19	6.00	6.00	0.72	-0.56	-0.04
A3	6.36	7.00	7.00	0.77	-1.22	1.73
A4	6.24	6.0	6.00	0.72	-0.57	-0.28
A5	6.37	7.00	7.00	0.74	-0.91	0.28
A6	6.40	7.00	7.00	0.76	-1.18	1.06
A7	6.32	6.00	6.00	0.70	-0.93	1.23
A8	6.32	6.00	7.00	0.70	-0.68	-0.10
A9	6.35	6.00	6.00	0.67	-0.94	1.54
A10	6.45	7.00	7.00	0.69	-1.21	1.46
A11	6.36	7.00	7.00	0.75	-1.04	1.00
A12	6.24	6.00	6.00	0.71	-0.56	-0.18
A13	6.26	6.00	7.00	0.78	-0.85	0.48
A14	6.34	6.00	6.00	0.70	-0.88	0.66
A15	6.25	6.00	7.00	0.79	-0.75	-0.06
A16	6.25	6.00	7.00	0.84	-1.16	1.42

The results of the EFA analysis using the Principal Component Analysis with non-perpendicular rotation Varimax extracted five components, including 16 behavioral indicators at an Eigenvalue stopping criterion of 1.175, with a total cumulative variance of 79.207% (Table 4). This indicates that the extracted factors explain 79.207% of the data variance. None of the behavioral indicators had a factor loading below 0.5, and the differences between the factors below were 0.3, indicating discriminant validity and convergence. Furthermore, the preliminary EFA generates three components for the competency framework instead of theoretical model's four component.

Table 5. Results of EFA Analysis

Behaviour indicator		Components		
Old code	New code	1	2	3
		KN	PR	EV
A4	KN1	0.940		
A2	KN2	0.939		
A1	KN3	0.931		
A3	KN4	0.926		
A6	KN5	0.876		
A5	KN6	0.835		
A10	OR1		0.964	
A11	OR2		0.957	
A12	OR3		0.954	
A9	OR4		0.879	
A13	OR5		0.782	
A8	OR6		0.743	
A7	OR7		0.713	
A15	AN1			0.875
A16	AN2			0.699
A14	AN3			0.684
Eigenvalue		7.783	3.715	1.175
AVE (%)		48.646	23.218	7.343
Cronbach's alpha		α_{KN} = 0.904	α_{PR} = 0.908	α_{EV} = 0.831

The Cronbach's alpha test results for the scales demonstrate their high reliability, with a Cronbach's alpha coefficient > 0.8 and a total correlation coefficient > 0.3, indicating that the model does not elim-inate any observed variables. In addition, the KMO coefficient = 0.878 > 0.5 with Sig Batlett's = 0.000 < 0.05 shows that the data is sufficient to conduct factor analysis. To show the order of the behavioral indicators based on how well they matched the parts of the teacher competency framework, we recoded the parts as Knowledge (KN), Oragnation (OR), and Analyzation (AN) and then ranked the be-havioral indicators accordingly.

Evaluation of the structural model of teachers' teaching experimental practice competencies

The composite reliability coefficients for all constructs were greater than 0.7 (CR: 0.800 to 0.969) (Ta-ble 6). Thus, from the research findings, it could be observed that the measurement scales of the com-ponents in the teacher's teaching experiment practice competency framework exhibited high internal consistency reliability.

Table 6. Results of Reliability and Convergence Assessment of the Scale

Components	Composite Reliability (CR)	Average Variance Extracted (AVE)
KN	0.969	0.837
OR	0.952	0.743
AN	0.800	0.574

The teachers' teaching experiment practice competency framework met the requirements for conver-gent validity, as the average extracted variance values were all above 0.5 (AVE: 0.574 to 0.837) (Table 6). By using the Heterotrait-Monotrait method, the teachers' teaching experiment practice competency framework met the criteria for discriminant validity. This is because none of the Heterotrait-Monotrait ratios (HTMT) for the pairs of components in the students' design thinking competency framework were higher than 0.85 (the highest being HTMTAN−OR = 0.687) (Table 7).

Table 7. Correlation Coefficient Between Concepts

	KN	OR	AN
KN	0.859		
OR	0.356	0.697	
AN	0.585	0.687	0.367

Teachers' teaching experimental practice competencies assessment tool after standardization

Table 8 presents the standardized components of teachers' practical teaching and experimental competence, derived from the structural model's results. From there, the study developed an assessment tool to help teachers monitor and record their competency development path during the learning process, thereby continuously improving and developing (Table 8). Furthermore, managers and experts in teacher training can use this tool to describe additional levels of proficiency and quality of behavioral indicators, creating a checklist tool for observing and assessing teachers' competency.

Table 8. Teachers' Teaching Experimental Practice Competencies Assessment Tool after Standardization

Components	Behaviour indcator	Behavior description
Professional knowledge in teaching experimental practice	KN1	Plan to conduct scientific experiments.
	KN2	Master teaching theories and teaching methods for practical experiments.
	KN3	Master scientific concepts, principles, and laws related to experiments.
	KN4	Implement regulations, safety rules, and experimental techniques.
	KN5	Select the right chemicals, store them safely, and label containers properly.

	KN6	Choose the right, sufficient, and appropriate tools for the experiment.
Organizing teaching and evaluating the level of experimental practice	OR1	Ask questions to guide students in observing phenomena to draw conclusions
	OR2	Handle situations and guide students in conducting experiments.
	OR3	Apply active testing and evaluation methods.
	OR4	Use experiments in combination with active teaching methods.
	OR5	Build a framework for testing and evaluating experimental results.
	OR6	Select experiments appropriate to teaching objectives and student subjects.
	OR7	Describe experimental phenomena, apply theoretical content to explain experimental phenomena.
Analysis of results in teaching experimental practice	AN1	Applying information technology in testing and evaluating experimental practice results.
	AN2	Using test and evaluation results to adjust teaching plans.
	AN3	Organizing for students to self-test, evaluate and peer evaluate.

Discussion

The Delphi method is widely recognized as an effective strategy for addressing complex tasks, such as developing criteria to assess the progression of teachers' competencies (Manizade & Mason, 2011; Muñiz-Rodrígue et al., 2017). In this study, which aimed to create a framework for assessing teaching competence, it is essential to highlight that the resulting criteria extend beyond a simple questionnaire. Instead, it comprises multiple components: critical sectors of competence; dimensions that represent the core aspects of each competence; indicators or criteria that operationalize dimensions to make them measurable; levels that denote proficiency; and captions that define and describe these levels. Collectively, these elements form a cohesive set of criteria to represent the development of teaching competencies. Competence is a multifaceted construct that requires careful observation and evaluation, as it is inherently dynamic (Jonnaert et al., 2007; Rich et al., 2020). It can often be understood as a combination of resources that interact in various ways (Harris et al., 2009). This study employed the Delphi method, which proved appropriate due to its structured approach to identifying iterative progress and achieving a high level of consensus among experts. The iterative development of the draft assessment criteria across successive rounds revealed that trainee teachers must, from the outset, demonstrate the ability to engage with global realities, show a willingness to adapt to diverse contexts, and take responsibility for experimental teaching practices.

Experimental teaching refers to the intentional and systematic influence of humans on objects in objective reality, enabling learners to acquire new knowledge by analyzing conditions under which the interaction occurs and the resulting outcomes (Steffe et al., 2012). The science curriculum and textbooks describe experimental teaching as a teaching activity that guides students in discovering new knowledge (Ministry of Education and Training, 2018). It also involves incorporating experimental content into practical exercises that illustrate theoretical concepts or facilitate the discovery of new insights. While previous studies on educational science have sought to enhance teachers' capacity for experimental teaching, much of the existing research has focused on individual components of experimental teaching competence. For instance, prior frameworks have primarily addressed specific competency groups such as knowledge (Bae et al., 2021) and organizational skills (Bae et al., 2021; Copriady, 2015). However, these studies still need to develop a comprehensive competency framework with detailed behavioral descriptions and measurable indicators to guide teachers holistically in improving their capacity for experimental teaching practices. This study fills this gap by creating a comprehensive competency framework specifically for teaching experimental practices. There are sixteen core competencies that were identified through the analysis process. These competencies include professional knowledge in teaching experimental practice, planning and evaluating experimental teaching activities, and analyzing the results of experimental teaching. This comprehensive approach is necessary to provide teachers with clear objectives and actionable strategies for enhancing their experimental teaching capacity and thereby supporting more effective science education.

This framework represents a pioneering effort in Vietnam to develop a tool for assessing teachers' teaching capacity within the context of educational program innovation. The framework identifies sixteen core competencies integrating knowledge, attitudes, and skills. However, several research gaps warrant further attention. Despite the competency framework's strong consistency, reliability, and validity, its adaptability to subjects beyond science remains unexplored. Similar competency-based assessments could benefit from disciplines such as technology, engineering, and art education, which rely heavily on practical or experimental activities. Additionally, implementing this framework in resource-limited contexts poses significant challenges. Many schools, particularly in underprivileged areas, may need more access to adequate materials, infrastructure, or teacher training programs for effective adoption. Future research should develop simplified or contextualized framework adaptations to address these limitations, such as leveraging alternative tools, community-based resources, or scalable training initiatives. Furthermore, further exploration is necessary to understand the long-term impact of the framework. Understanding how these competencies influence teacher development, instructional quality, and student outcomes is crucial to assessing the framework's long-term effectiveness. Longitudinal studies could also show how competencies evolve and whether the framework fosters sustained professional growth. Addressing these research gaps would enhance the framework's applicability and scalability and ensure its relevance and impact across a broader range of subjects and educational contexts.

CONCLUSION

The results from the Delphi method showed that sixteen core competencies emerged from the analysis process, including a combination of knowledge, attitudes, and skills. The authors believe that achieving and operating these competencies in the school context can be quite complex and multifaceted. At the same time, the study developed and standardized an assessment tool for teaching experimental practice competencies to teachers in the subject of science. The revised tool includes three components of competencies: Professional knowledge in teaching experimental practice (KN), Organizing teaching and evaluating the level of experimental practice (OR), and Analysis of results in teaching experimental practice (AN).

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